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GROUNDWATER RESOURCES EVALUATION

O'LEARY

THE CANADA – PRINCE EDWARD ISLAND
WATER MANAGEMENT AGREEMENT

Environment Canada Environnement Canada

Prince Edward Island
Department of the Environment

GROUNDWATER RESOURCES EVALUATION

O'LEARY

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Groundwater Resources Evaluation - O'Leary

Executive Summary

A test drilling program and a review of the available hydrogeological data indicate that the natural quantity and quality of groundwater resources in much of the community of O'Leary are generally good and sufficient to meet the community's needs. There is however, a significant portion of the community that has historically experienced rather severe groundwater quality problems. Some of these problems are manmade, such as petroleum contamination, high nitrate concentrations and bacterial contamination, while others appear to be primarily of natural origin. While some water quality problems such as high iron and manganese concentrations which are frequently associated with older, shallower wells, may be prevented by more modern well construction techniques, problems such as contamination of groundwater by petroleum products are more difficult to address.

The test drilling program conducted under this project has identified a suitable location for the development of a central water supply, which would provide a sufficient quantity of water to meet the communities needs, as well being generally suitable for the implementation of measures to provide for the protection of groundwater quality. The existing test wells are estimated to have a combined capacity of 8.3 L/sec (717 m^3/day), sufficient capacity to supply the water needs of the existing population. In addition, the test site as sufficient additional room to construct additional wells if necessary.

In light of the serious water quality problems in the north-eastern part of the community, and the availability of an alternate source of water within the community boundaries, the community should give consideration to developing this source of supply to service at least the portions of the community which have experienced water quality problems. The community should also take steps to implement well field protection measures, to ensure the future integrity of groundwater resources in this area.

Acknowledgments:

This study was completed as a part of the Canada - P.E.I. Water Management Agreement, a joint initiative of Environment Canada and the Prince Edward Island Department of the Environment. The author wishes to acknowledge the efforts of Don Carey of Jaques, Whitford and Associates, who oversaw the initial planning of the program. Thanks go also to the many staff of the P.E.I. Department of the Environment for the many stimulating and fruitful discussions on various aspects of this work. Particular gratitude is expressed to Paul Baker for his able support in various office and field activities during the course of the program and to Don Jardine and Rory Francis for guidance throughout various phases of this work. John Gibb of Environment Canada was instrumental in various parts of this program and his patient review of the manuscript is appreciated.

Groundwater Resource Evaluation
O'Leary

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1. Introduction

This report documents the findings of a study of the groundwater resources of the Community of O'Leary, conducted as part of the Groundwater Resource Evaluation Project, under the Canada - Prince Edward Island Water Management Agreement. The Groundwater Resource Evaluation Project is intended to investigate, through a series of studies, the available groundwater resources in selected communities across the Island, and to make recommendations regarding the most appropriate manner of developing and protecting this resource, in light of the physical constraints and expected water needs of each community.

In this study data collected through test drilling, pump testing and field reconnaissance, augmented by existing data on the groundwater resources of O'Leary are assessed, and conclusions drawn regarding the availability and quality of groundwater resources in the study area, and the most appropriate manner of developing and protecting this resource for future use.

2. Geography

2.1 Physical Geography

O'Leary is located near the western end of Prince Edward Island, 120 km. from Charlottetown. The topography is generally flat to gently undulating with slopes to the east and southeast, except in northern sections of the community, where the land slopes towards the unnamed creek which runs eastward across the northern end of the Gaspe Road. The highest elevations occur in the north western area of the community at 36 m. The community covers an area of 145 ha. There are some low - lying swampy areas, especially in the northern sections of the community and along the creek, otherwise there are no other significant water courses or surface water bodies.

2.2 Cultural Geography

The community of O'Leary is situated in the midst of a primarily agricultural area with potatoes being the main cash crop. Service and agricultural supply industries are the main commercial activities in the community with a dairy, fertilizer plant, service stations , a variety of retail stores, and construction operations. In addition there are schools, a hospital, veterinary clinic and a regional services centre.

The population, according to the 1986 census was 823, and although population changes in the community are not well documented, it is expected that growth in the community will be modest in the foreseeable future.

3. Geology

3.1 Surficial Geology

Overburden in the O'Leary area consists primarily of clay - silt phase glacial till (Prest, 1973). These deposits consist of a compact ground moraine deposited under actively flowing ice of the last (Wisconsin) ice age. From previous information (Pollit, 1951) and the stratigraphic logs on the well drillers reports, overburden thickness averages 3.5 m , with a range from less than 1 m to approximately 8 m.

The soil survey report (MacDougal & Veer, 1981) indicates soils in this area fall into two main categories. The western third of the community is underlain by a mixture of the Charlottetown series (60%), and O'Leary series soils (30%). The Charlottetown series soils are moderately coarse textured, strongly acidic developed on gently undulating relief, with a well-drained to moderately well-drained surface and moderate to slow subsoil permeability (less than 1 x 10^{-4} cm/sec). The O'Leary series soils are medium textured acidic soils developed on gently undulating relief, with moderately well-drained surface and slow subsoil permeability and high water tables.

The remainder of the community is underlain by a mixture of Duvar series soils (60%) and Margate series soils (30%). The Duvar series are medium textured, acidic soils developed on gently undulating relief, with imperfect surface drainage, slow to very slow subsoil permeability and seasonally high water tables. The Margate series are medium textured, acidic soils, also developed on gently undulating relief, with poor surface drainage, very slow subsoil permeability, and deep water tables.

3.2 Bedrock Geology

Bedrock consists of Upper Pennsylvanian to Lower Permian sedimentary strata of van de Poll's Megacyclic Sequence II (van de Poll,1981) which together with the other three megacyclic sequences identified on Prince Edward Island are believed to be slightly younger stratigraphic equivalents of the strata comprising the upper portions of the Pictou Group found elsewhere in the Maritime Provinces. The sequence consists of red conglomerate, sandstone and siltstone, occurring in repeated fluvial cycles generally becoming coarser with depth, with the basal conglomerate overlying conformably the sandstone and siltstone of Megacyclic Sequence I. Lateral continuity of individual facies is generally limited as is frequently typical of recurring fluvial cycles. Well drillers reports indicate that sandstone with lesser amounts of siltstone and claystone are the dominant lithologies encountered in wells drilled in the area.

Lithological and geophysical logs of two test holes drilled for this project (see Figure 5) indicate that bedrock is composed of a complex interbedded sequence of sandstones siltstones and claystone, typical of fluvial deposition. While discrete sandstone and claystone beds of considerable thickness occur, a major portion of each section is composed of finely interbedded

sandstone and shale. Individual sandstone beds reach a maximum thickness of approximately 5 m, and the thickness of individual shale sequences generally do not exceed 2.5 m. Typical of fluvial sediments, lateral continuity of individual beds is likely to be limited, and only a crude correlation can be made between different zones in the section, even over the short distance between the two test wells (approximately 93 m).

4. Hydrogeology

4.1 Existing Well Data

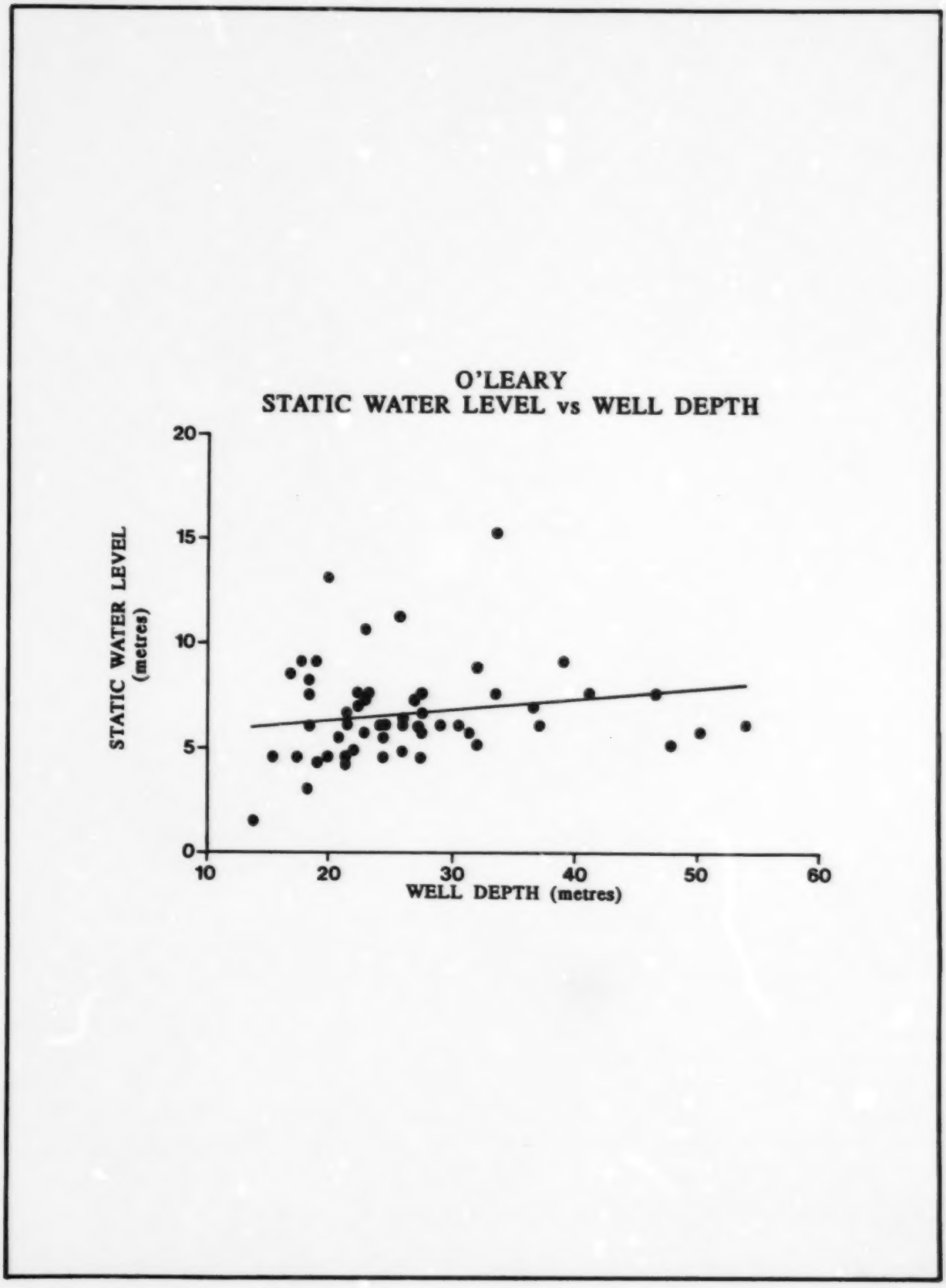
The P.E.I. Department of the Environment has well drillers reports for approximately 125 wells drilled in the community since 1970. The average well depth in the community is 25 m with a maximum well depth of 46.6 m (excluding test holes drilled as a part of this program). The average casing length for wells in the community is 13 m, although there is quite a range in casing lengths with a number of wells constructed with greater than 15 m of casing, and occasionally exceeding 30 m. Most older domestic wells have casing lengths not exceeding 9 m.

The static water level in the community averages 6.7 m below ground level and reported levels range from 1.5 m to 15 m. This is a surprising range of water levels for an area of such gentle topography, especially considering the relatively similar depths of wells represented. It is possible that some of these measurements have been made immediately after bailing or development of the well, thus reflecting water levels prior to complete recovery of the well. In addition static water level measurements have been made at various times throughout the year and variations from seasonal fluctuations in water levels is also likely to be reflected in this data. Although there are no continuously monitored wells in the community itself, hydrographs from an observation well in Bloomfield indicate average seasonal water table fluctuations on the order of 3.8 m

The static water level data exhibit a weak correlation with well depth, with the static water levels of deeper wells generally being lower those recorded for shallower wells (see Figure 1) suggesting that the area is dominantly a groundwater recharge area.

The average well yield in the area, as reported on the well drillers reports, is 0.68 litres per second (L/sec) with a maximum of 2.3 L/sec (excluding the test wells drilled under this project). The minimum well yield recorded on the well drillers reports is 0.38 L/sec. While the well yields reported in these logs are somewhat low relative to some other locations on the Island, it should be noted that most of the wells represented in the records are domestic wells which would only be drilled to a depth sufficient to assure sufficient water for household use. It should also be recognized that most of the reported well yields have been determined by short duration (frequently 10 minutes or less) blow or bail tests, and therefore have only limited accuracy.

Figure 1


O'LEARY
STATIC WATER LEVEL vs WELL DEPTH
STATIC WATER LEVEL (metres)
20
15
10
5
0
10
20
30
40
50
60
WELL DEPTH (metres)

To make the well yield data from the well drillers reports more meaningful, the differences in well depth, or more precisely, the difference in the length of the saturated portion of the aquifer, below the bottom of the casing, in individual wells should be taken into account.

All other factors being equal, a deeper well with a greater depth of open hole below the water table would be expected to yield a greater quantity of water than a shallower well. To evaluate the water yielding characteristics of the aquifer therefore, it is useful to take into account the saturated thickness (water bearing portion) of each well when considering well yields.

As is common on P.E.I., individual aquifers are often difficult to identify , especially as the flow of water through fractures is probably more significant than primary porosity in determining hydraulic conductivity. (Francis, 1981). For these reasons the entire saturated thickness of sediments penetrated by well is approximated here as a single semi- confined aquifer.

As a measure of aquifer yield, the yield per metre of saturated thickness penetrated for each well has been calculated. The average yield per metre of saturated thickness in litres per second per metre (L/sec/m) is 0.069, ranging from a minimum of 0.034 L/sec/m to a maximum of 0.194 L/sec/m. This would mean that on average, a well with the lower 12 m saturated would be expected to yield approximately 0.75 L/sec. The test holes drilled under this program had yields/ m of saturated thickness of 0.077 and 0.092 L/sec/m respectively for test holes OL-1 and OL-2. The distribution of yields per saturated thickness for wells in the community is shown graphically on Figure 2.

There appears to be only a very weak correlation between yield per foot of saturated thickness and well depth (see Figure 3). Nonetheless, it appears that the more shallow water bearing zones are more productive than deeper zones, but any differences noted are small. Two factors could account for this occurrence; open fractures, and thus the available conduits for the transmission of water are more frequent at shallower depths; and secondly well drillers tend to drill only until a sufficient quantity of water is found. Thus in less productive areas, wells will tend to be deeper, thus biasing the sample population. In light of the small differences noted and the weakness of the correlation, water quality constraints would probably be more significant in determining the appropriate depth of a well than water quantity considerations.

It must be noted that the foregoing analysis represents only an approximation of well yield in the area because of the limited duration and accuracy of yield testing and other shortcomings in the analysis and interpretation of the data. For instance it should be noted that the static water levels used have been measured during different times of the year (and probably to varying degrees of accuracy) thus adding a temporal variation to the data not accounted for in this analysis.

Figure 2

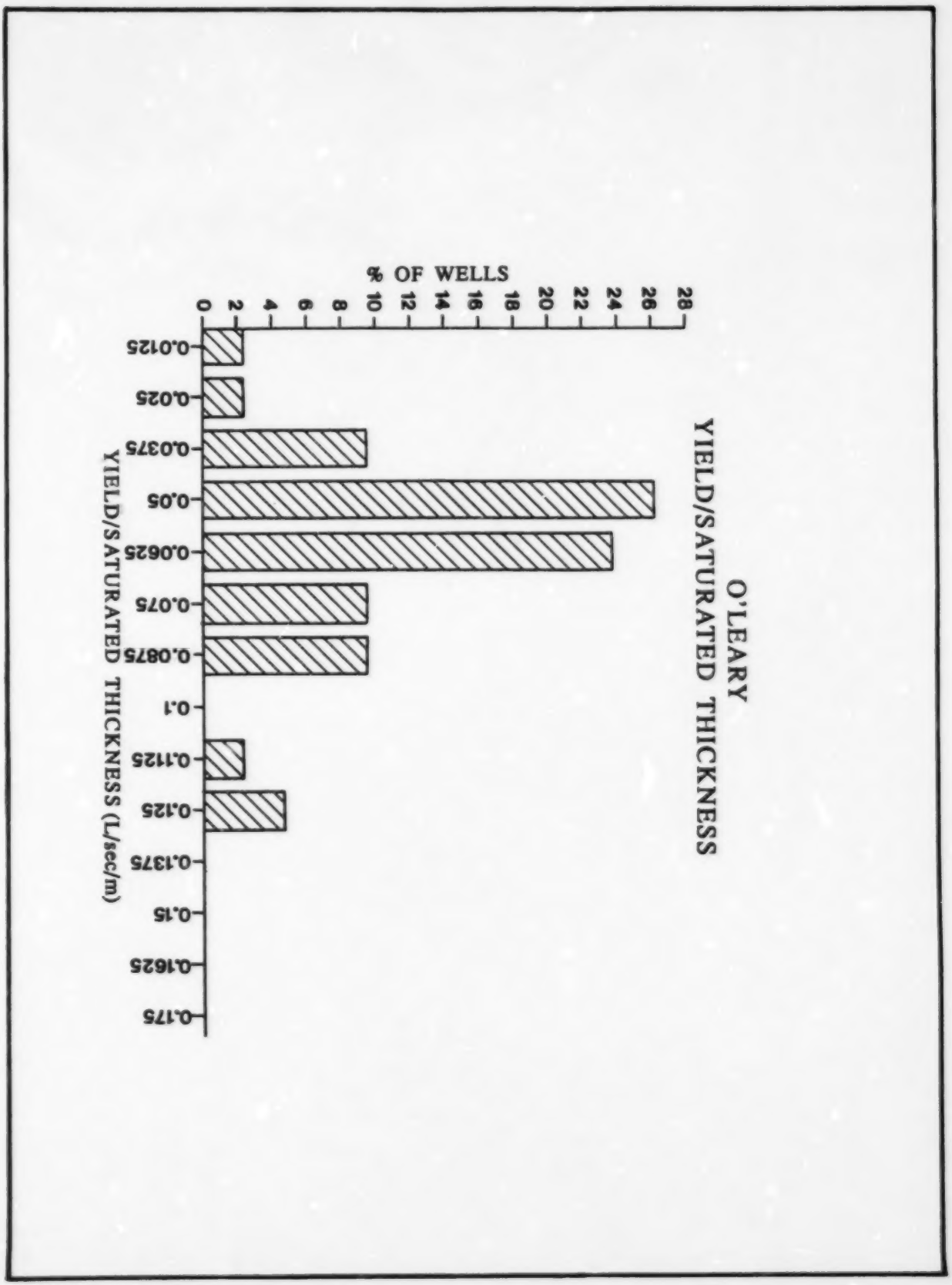
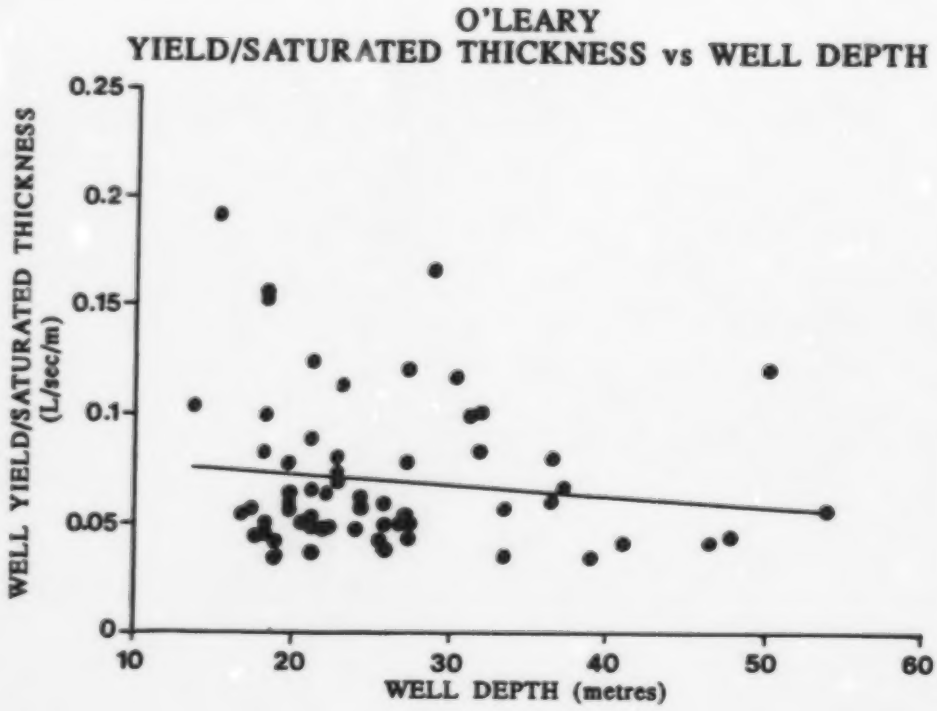

O'LEARY
YIELD/SATURATED THICKNESS
% OF WELLS
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
YIELD/SATURATED THICKNESS (L/sec/m)
0.0125
0.025
0.0375
0.05
0.0625
0.075
0.0875
0.1
0.1125
0.125
0.1375
0.15
0.1625
0.175

Figure 3


O'LEARY
YIELD/SATURATED THICKNESS vs WELL DEPTH
WELL YIELD/SATURATED THICKNESS (L/sec/m)
0.25
0.2
0.15
0.1
0.05
0
10
20
30
40
50
60
WELL DEPTH (metres)

In spite of these short comings the data do suggest that in most cases a well drilled to a depth of 30 metres should provide more than an adequate supply of water for domestic purposes, but the likelihood of obtaining high yields (>10 L/sec) from individual production wells is limited.

4.2 Test Drilling & Pump Testing

Field investigations associated with this project have involved selecting sites and conducting test drilling & pump testing, as well as a evaluating locations in terms of their potential as protected sources of groundwater supply.

4.2.1. Site Selection

Three factors were considered in the selection of a site for test drilling:

1) The area should be located such that well field protection measures could be implemented,

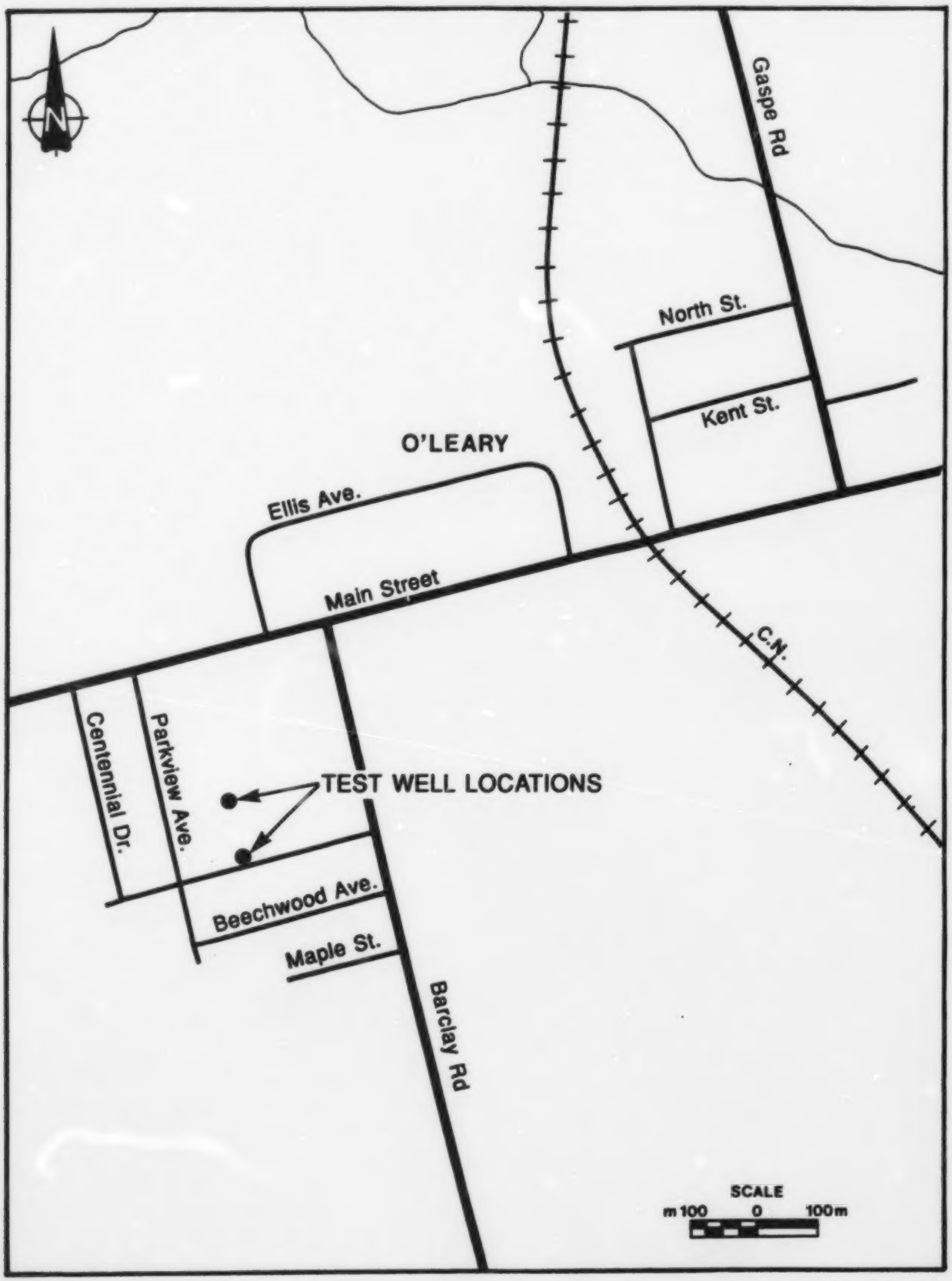
2) the area should be one which would maximize the probable yield of the test wells,

3) existing water quality at the site should be acceptable.

The most limiting of these factors were the availability of land in areas where suitable water quality could be expected, and where well field protection measures could be implemented. A large portion of the community (most of the eastern end) has experienced serious water quality problems and there is not an abundance of open land in the community that is not currently developed. Available well information did not indicate any particular area where above-average yields could be expected.

For these reasons the park land currently owned by the community near the high school was chosen. Other land to the north of the community was considered but rejected for the time being for several reasons. First it is outside the community boundaries and thus no direct control of land use could be exercised. Secondly the land is privately owned and the purchase of the necessary land would place an additional financial burden on the community if it chose to develop the wells as part of a central water supply. Finally the land in question is productive agricultural land. To take this land out of production (assuming that the extensive application of agricultural chemicals would not be acceptable in the vicinity of the production wells) would create a land use conflict, involving a trade off between the agricultural value of the land vs. its benefit as a source of groundwater supply.

Figure 4


N
Gaspe Rd
North St.
Kent St.
O'LEARY
Ellis Ave.
Main Street
C.N.
Centennial Dr.
Parkview Ave.
TEST WELL LOCATIONS
Beechwood Ave.
Maple St.
Barclay Rd
SCALE
m 100 0 100m

The site chosen for the test wells is adjacent to land occupied by the high school shown on Figure 4. This area could also prove suitable for development of a water supply, and the associated land use activities would not likely have a detrimental effect on groundwater quality.

4.2.2 Test drilling:

Two test holes were drilled at locations approximately 93 m apart at the site identified on Figure 4. Each test hole was 15 cm in diameter and drilled to a depth of 60 m. Drilling was conducted using an air rotary drill rig. Samples of drill cuttings were collected and logged at 3 m intervals and/or at changes in the formation. The wells were cased to a depth of 12 m feet and the casing sealed with two 22 kg bags of granular bentonite in each well.

Each well was subsequently logged (lithology, gamma, caliper and flowmeter.) The caliper log for test hole OL-1 indicated a slight bowling out of the hole immediately below the casing, otherwise both holes appeared to be smooth. Flowmeter logs indicated a slight downward gradient in both holes, but no zone of particularly strong flow was apparent. The lithologic and gamma logs are shown on Figure 5. At the completion of drilling, the static water level in test hole OL-1 was 7.14 m below the top of casing and for test well OL-2 the static water level was 6.58 m below the top of casing.

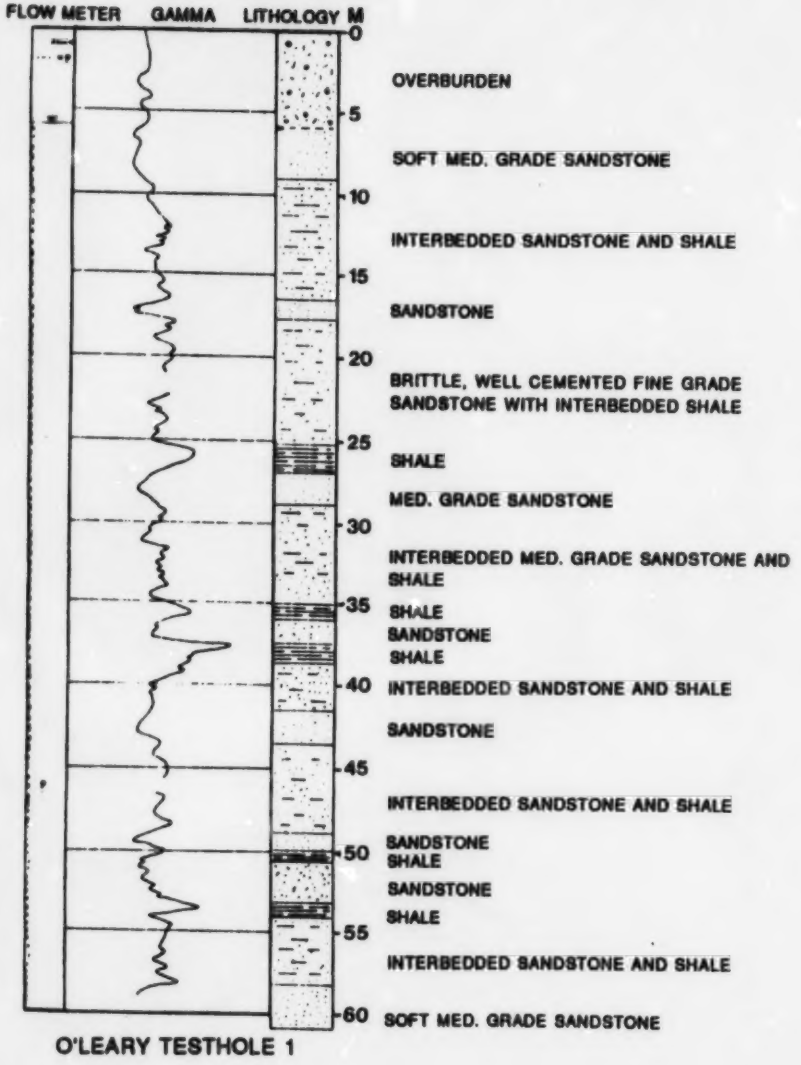
4.2.3 Pump Testing

The pump testing phase of the program consisted of two types of tests. Following completion of the wells, each well was subjected to a step drawdown test, to assess well performance and to select the most appropriate pumping rate for a constant rate test. The constant rate test was performed to assess the aquifer characteristics in the immediate area of the wells, and to observe well performance over a longer period of time.

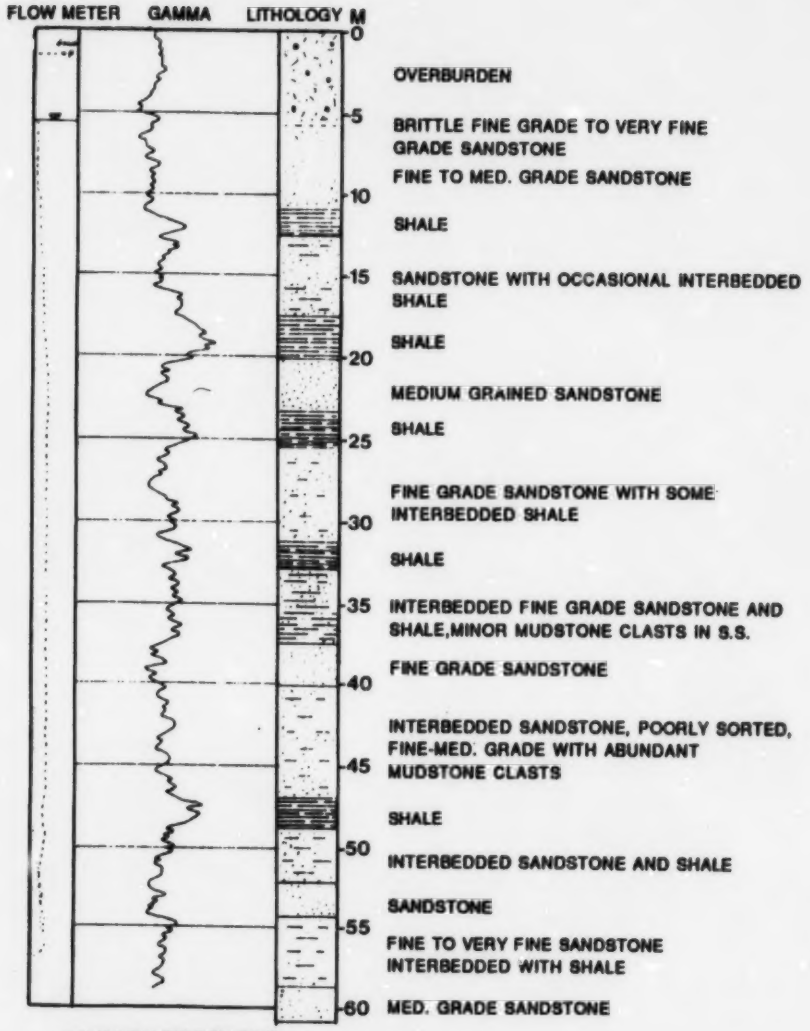
Step drawdown tests were conducted using a 7 1/2 horse power submersible pump set at a depth of 27 m. Water level measurements were made through a drop pipe and the discharge was measured by timing the rate at which a 45 gallon barrel was filled.

Test well OL-1 was to be tested for three successive half hour steps at rates of 3.8, 7.6 and 11.4 L/sec respectively, although during the test it became apparent that a pumping rate of 7.6 L/sec could not be sustained for any prolonged period of time. Testing of test well OL-2 was to be conducted at rates of 3.4, 4.5 and 5.3, but again well performance was poorer than expected and a pumping rate of 3.8 L/sec or more could not be sustained for prolonged periods of time. The results of the step drawdown tests are summarized in Table 1.

Figure 5



O'LEARY TESTHOLE 1



O'LEARY TESTHOLE 2

The results for test well OL-1 indicate a decreasing specific capacity with increasing pumping rate. Specific capacity is a measure of the drawdown of the water level in a well for a given pumping rate. The decrease in specific capacity with increasing pumping rate is a commonly noted feature, and is a reflection of decreasing well efficiency with increasing pumping rates.

Table 1

Test Well OL-1			Test Well OL-2		
Q * (L/sec)	Drawdown (m)	S.C.** (L/sec/m)	Q* (L/sec)	Drawdown (m)	S.C.** (L/sec/m)
3.8	8.2	0.47	3.0	14.6	0.21
4.9	10.7	0.45	3.8	17.7	0.22
7.6	18.6	0.42	-	-	-

* Q = pumping rate
** S.C. = specific capacity

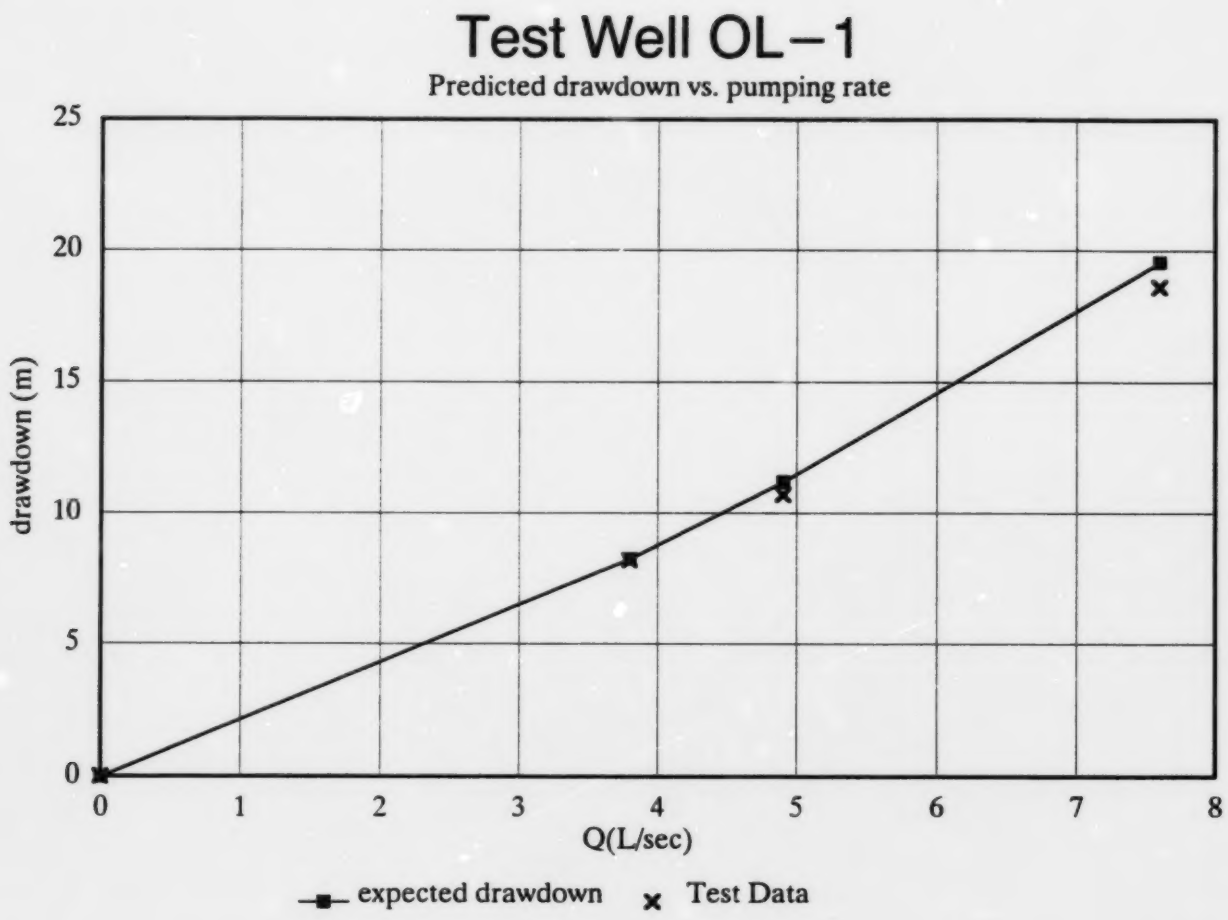
This decrease in well efficiency is usually attributed to increasing head losses in the well as a result of turbulent flow in and around the well bore at higher pumping rates.

Figure 6 shows the theoretical relationship between pumping rates and drawdown in the well, based on the step drawdown data. It should be noted that this data applies, strictly speaking, only for pumping periods of 1/2 hour; actual drawdown for longer pumping periods are likely to be somewhat greater. In addition any extrapolation beyond of these values beyond the highest pumping rate should be made with caution, as the mathematical function used to calculate these values is only an approximation. Figure 6 indicates that the efficiency of test well OL-1 begins to decline at a greater rate beyond a pumping rate of 4.9 L/sec.

The results from test well OL-2 show a different, somewhat unusual response to an increase in pumping rate. In this case, the specific capacity of the well actually increased marginally as the pumping rate was raised form 3.8 L/sec to 4.9 L/sec. The most plausible explanation for this behavior is that the well was continuing to develop as the testing was conducted.

It is interesting to note that while the actual drawdown in the well during the subsequent 48 hour constant rate test was 13.7 m, the predicted drawdown based on calculations using the aquifer parameters derived from the test is only 7.9 m. This indicates that the well is only approximately 57% efficient or, stated another way, almost half of the drawdown in the pumping well is a result of head losses due primarily to turbulent flow near the well bore.

Figure 6


Test Well OL–1
Predicted drawdown vs. pumping rate
drawdown (m)
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
Q(L/sec)
expected drawdown
Test Data

One of the practical implications of this is that although the drawdown in the pumping well may be quite significant, the amount of drawdown in adjacent wells as a result of pumping this well should be minimal. This could be all the more important in an area where land availability for the development of water supplies is somewhat restricted.

As can be seen from Table 1 the performance of test well OL-2 was poorer than test well 1, with a specific capacity of only 0.2 L/sec/m at a pumping rate of 3.8 L/sec . With only two steps for the step drawdown test, it is more difficult to assess well efficiency. Given that the drawdown at even modest pumping rates was greater than in test well OL-1, and that aquifer conditions should be expected to be similar for the two wells, it is probably safe to conclude that the efficiency of this well was poorer, and that pumping should be restricted to rates of around 3.5 L/sec.

It should be noted that the non-linear relationship between pumping rate and drawdown means that it is difficult to extrapolate too far beyond the rates at which the testing is conducted when determining the expected drawdown in a well, for a given pumping rate. The step drawdown test data suggest that test well OL-1 probably could be pumped safely at a rate of 5 to 5.5 L/sec, while test well OL-2 is unlikely to sustain a pumping rate of more than 3.5 L/sec.

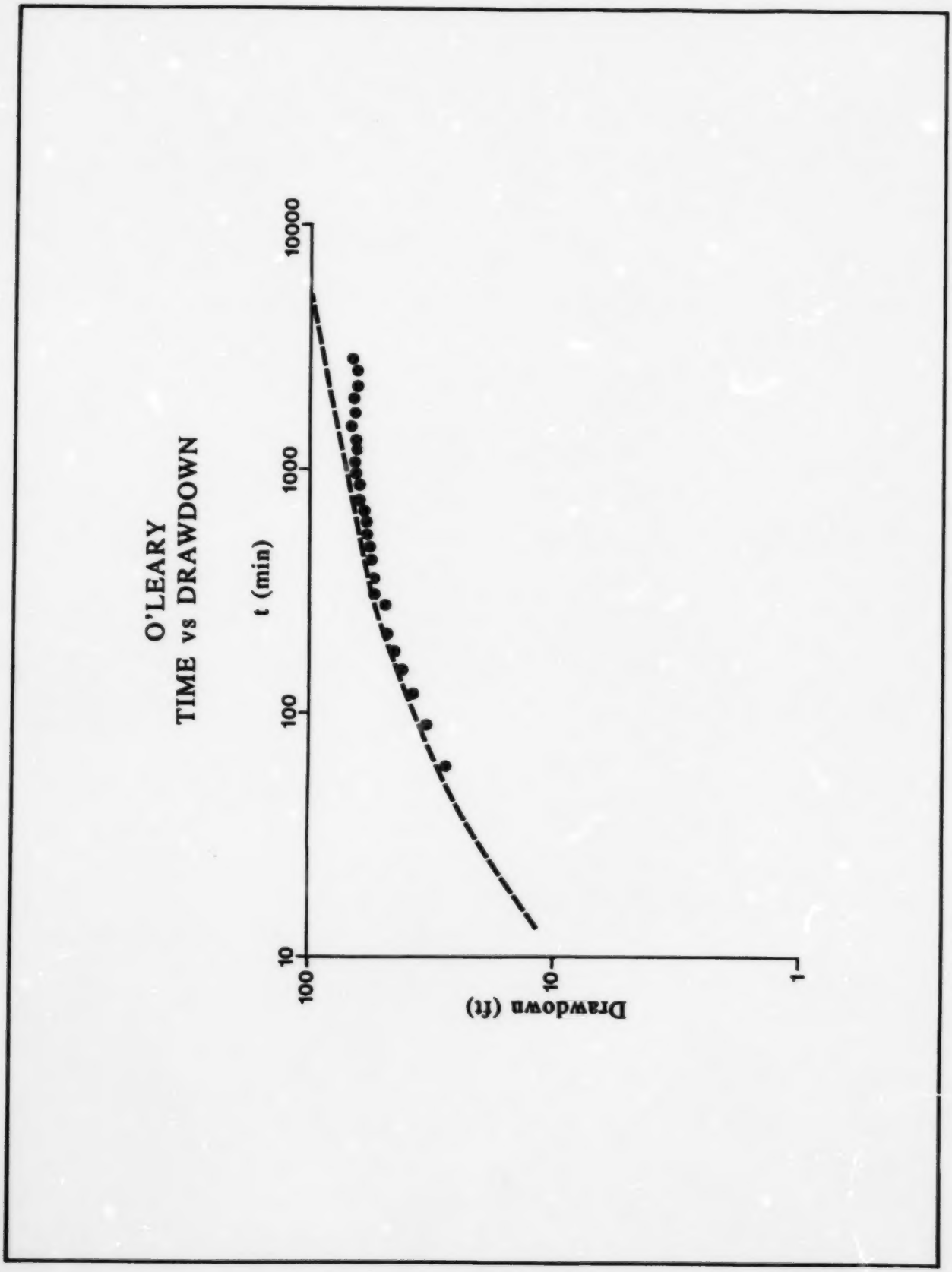
Based on these results test well OL-1 was selected for the constant rate test with test well OL-2 being used as an observation well. The well at the nearby Senior Citizens Home was also monitored during the constant rate test to ensure there was no disruption of water supply to that facility. These measurements were not used in calculation of aquifer parameters, as the pumping of this well to service the facility would partly mask the effects of drawdown which resulted from pumping test well OL-1.

Test well OL-1 was initially subjected to a 48 hour test at a rate of 5.7 L/sec. Following problems with pumping equipment less than halfway through the test, the test was restarted at a rate of 4.9 L/sec and ran successfully for 48 hours.

At the end of the test, 13.7 m of drawdown was recorded in the pumping well, with 1.6 m and 0.8m of drawdown in the observation well (test well OL-2) and the well at the Senior Citizens home respectively. Test data was analyzed by the Theis curve fitting technique (manual and computer generated fits), the Jacob method (manual and computer derived values) and by analysis of recovery data. Calculated transmissibility and storativity values are presented in Table 2.

The constant rate test data indicates a departure from the ideal type curve for confined aquifer conditions and after a period of approximately 16 hours of pumping. This effect is usually explained as being a result of recharge or "leakage" from overlying or underlying aquifers. While the rock strata in the vicinity of the wells may not be typical of a classical "semi - confined aquifer, this feature may reflect "leakage" of groundwater stored in adjacent strata or simply recharge resulting from the discharge from the pumping well during testing (attempts to

Figure 7


O'LEARY
TIME vs DRAWDOWN
t (min)
10000
1000
100
10
100
10
1
Drawdown (ft)

direct pumping discharge into the storm sewer were only partly successful due to freezing conditions). Figure 7 shows the time-drawdown relationships of the test (on a log - log scale), as observed at the observation well.

Table 2. Analysis of Pump Test Data

Method of analysis	Transmissibility (m^2/day)	Storativity
Observation well data		
Theis	70.3	1.3×10^{-4}
Jacob (manual)	82.5	8.3×10^{-5}
Jacob (computer fit)	103.8	9.3×10^{-3}

The average transmissibility value from analysis of the pump test data is approximately 86 m^2/day. Storativity values show a large range with an average value of 3.2×10^{-3}.

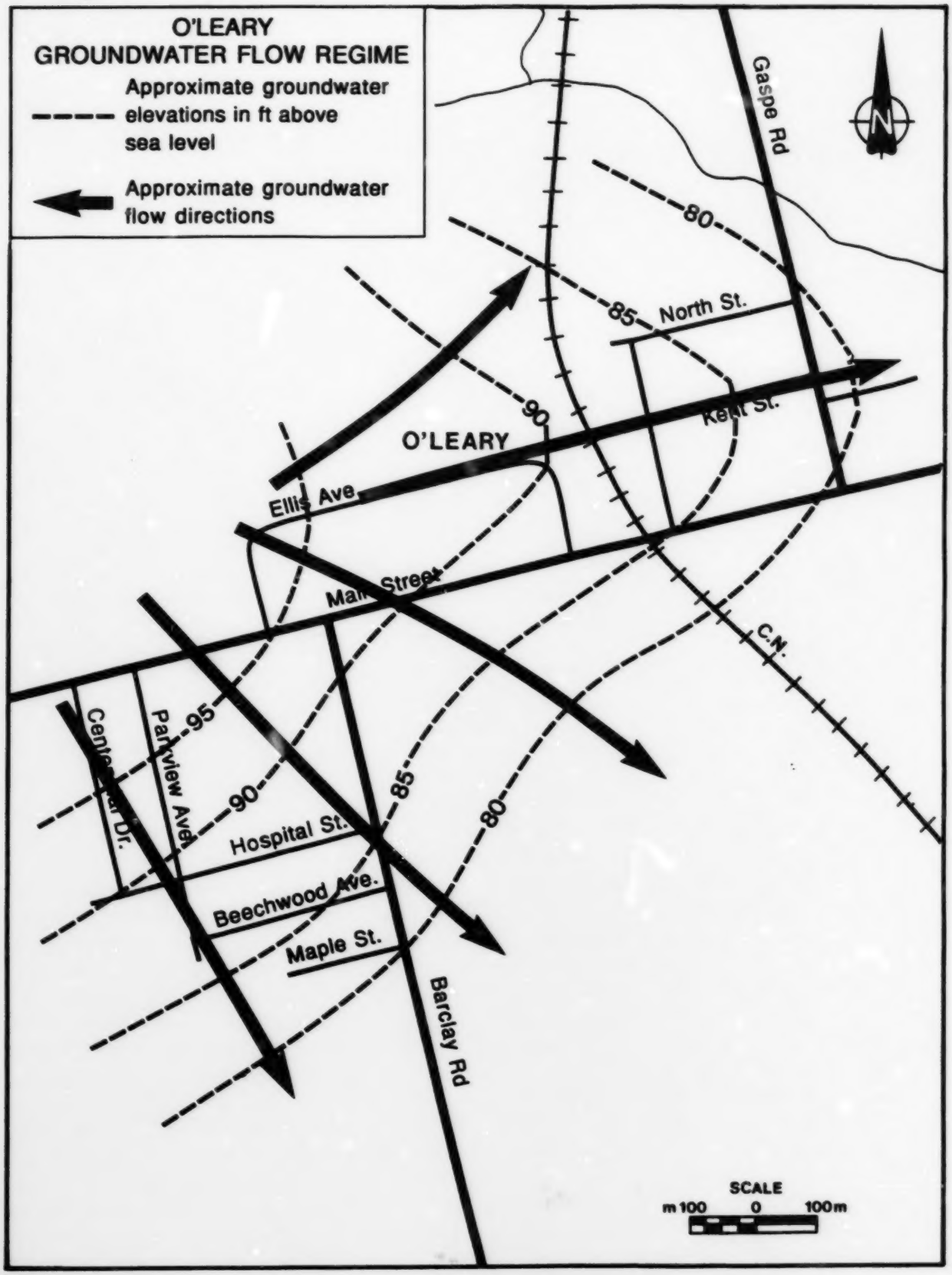
4.3 Groundwater Flow Regime

A comprehensive picture of the groundwater flow regime in O'Leary is difficult to develop because of the subdued topography, the static water level measurements and well information have varying accuracy, and most wells in the area have only penetrated the top 30 m of the aquifer(s).

The limited evidence suggests that groundwater flow follows the topographic gradient which is generally northwest to southeast throughout most of the community except in the northeastern part of the community, where the migration of contaminant plumes and the topographic gradient would suggest a more easterly to northeasterly flow direction. A rather tentative approximation of water table elevations and groundwater flow directions in the community is presented in Figure 8. The data from which this picture is derived are all in the English system of units and no conversion to metric units has been made.

In all parts of the community, hydraulic gradients appear to be very low, generally not exceeding 1% . This low gradient combined with the relatively low permeability of the underlying aquifer(s) would suggest that volumetric groundwater flux would be rather limited. Considering that secondary permeability (fractures) is probably dominant over intergranular permeability, the effective porosity of the rock is rather low thus leading to potentially higher groundwater velocities in individual fractures. Thus, while the actual volume of flow per unit cross sectional area may be rather limited, it might be expected that groundwater velocities could be appreciable even under the very low gradients found in the area.

Figure 8


O'LEARY
GROUNDWATER FLOW REGIME
Approximate groundwater elevations in ft above sea level
Approximate groundwater flow directions
Gaspe Rd
N
80
85
North St.
90
Kent St.
O'LEARY
Ellis Ave
Main Street
C.N.
95
90
85
80
Parkview Ave
Hospital St.
Beechwood Ave.
Maple St.
Barclay Rd
SCALE
m 100 0 100m

The available well data does not permit the definition of specific recharge and discharge areas within the community. However, the entire area is likely a recharge area with discharge being restricted to local stream courses. The general trend of decreasing pieziometric head (water levels) with increasing well depth described in section 4.1 would tend to support this hypothesis.

5. Groundwater Quality

5.1 Baseline water quality

Water quality data from routine samples collected throughout the community by the Department of the Environment indicate that the groundwater in the area is of calcium bicarbonate type, and that the water generally is very hard, with only a few results less than 100 mg/l total hardness. The relative concentration of major ions in the water is shown in Figure 9.

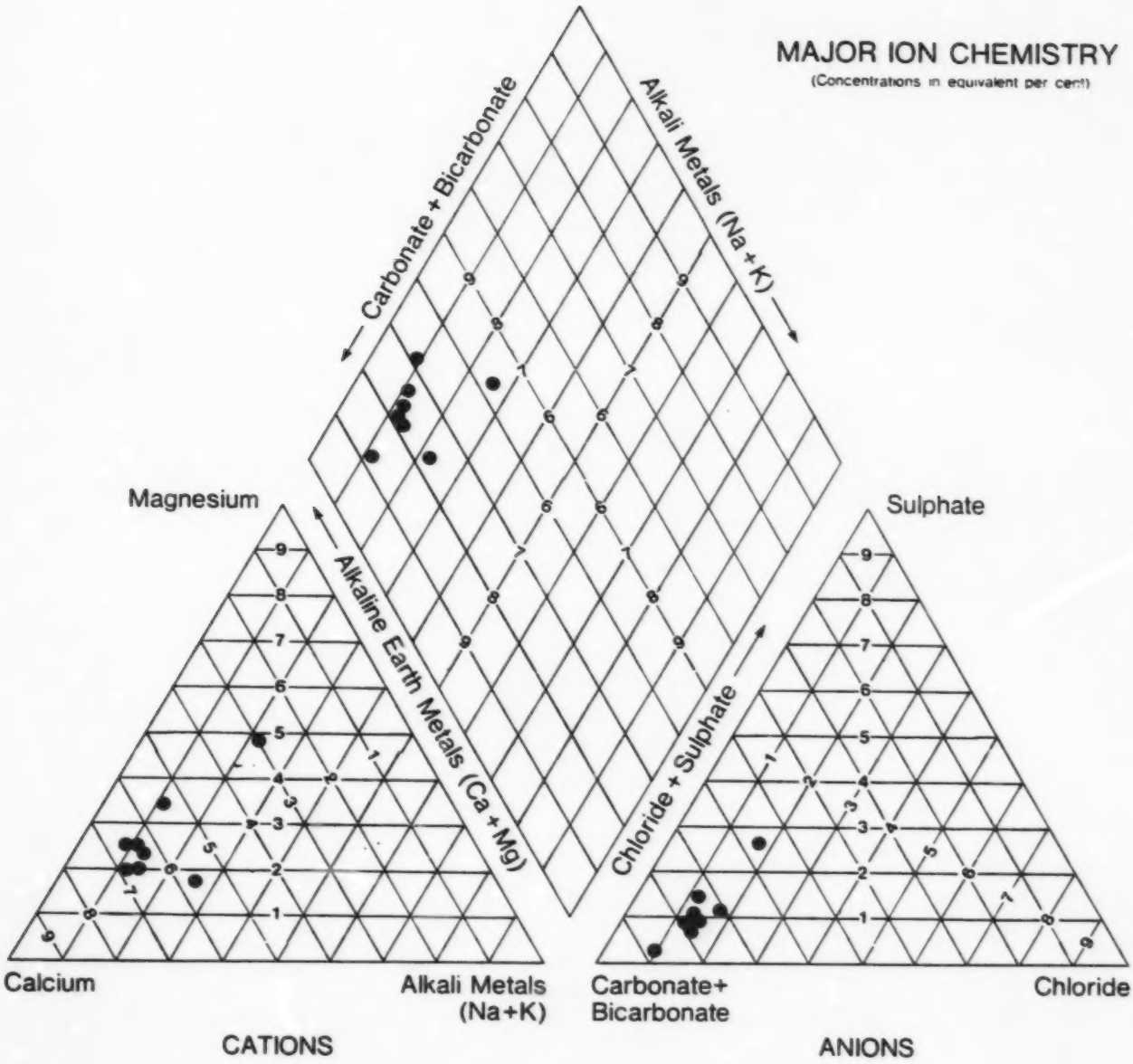
Analyses of water from some areas of the community frequently show the occurrence of high concentrations of iron and manganese, especially in the eastern part of the community. These higher concentrations of iron and manganese, are associated with reduced groundwater which may also exhibit a swampy or musty odor. Frequently, but not exclusively, these waters are from older shallow wells which probably only tap the near surface levels of the aquifer.

Jardine (1976) noted that the concentration of some dissolved constituents of the water such as chlorides and hardness decline with depth. In the same study reported values for nitrate concentrations ranged from 1.6 to 37.5 ppm as NO3 (0.4- 8.5 mg/L nitrate N) . Nitrate-N concentrations reported on water quality analysis in departmental records up to 1987 (50 samples) show a range of values from less than 0.2 mg/L up to 14.0 mg/L, although only four of these analyses indicate values exceeding the maximum acceptable concentration (MAC) set out in the Guidelines for Canadian Drinking Water Quality (Health and Welfare Canada, 1989). Two of these analyses represent samples from the same location, the site of a former fox farm. Thus while these later data show slightly higher average nitrate concentrations than the survey conducted by Jardine in 1976, any differences noted are small, and not sufficient to establish any significant trends.

5.2 History of Water Quality Problems

There are several serious water quality problems in the community of O'Leary. Of these, the one which has had the greatest impact on the availability of water of suitable quality has been contamination of groundwater by petroleum products. Two major gasoline contaminant plumes have affected a number of wells in the eastern end of the community. There have also been 6 smaller spills that have had only a local effect. The first major spill was of 36,000 L of

Figure 9


MAJOR ION CHEMISTRY
(Concentrations in equivalent per cent)
Carbonate + Bicarbonate
Alkali Metals (Na + K)
Alkaline Earth Metals (Ca + Mg)
Chloride + Sulphate
Magnesium
Sulphate
Calcium
Alkali Metals (Na+K)
Carbonate+ Bicarbonate
Chloride
CATIONS
ANIONS

kerosene from the Imperial Oil bulk plant at the corner of Willow Ave. and North Street in 1965 or 1966. The second major spill was 22,000 L of gasoline from the Texaco service Station on Main Street discovered early in 1986.

To help delineate the extent of some of the more persistent water quality problems, a survey was conducted in the eastern portion of the community. The questionnaire was delivered to all residential and commercial buildings in the area east of the railway tracks, and picked up one week later. The form included questions regarding problems with water supplies experienced in the past and on going problems as well as questions regarding well construction.

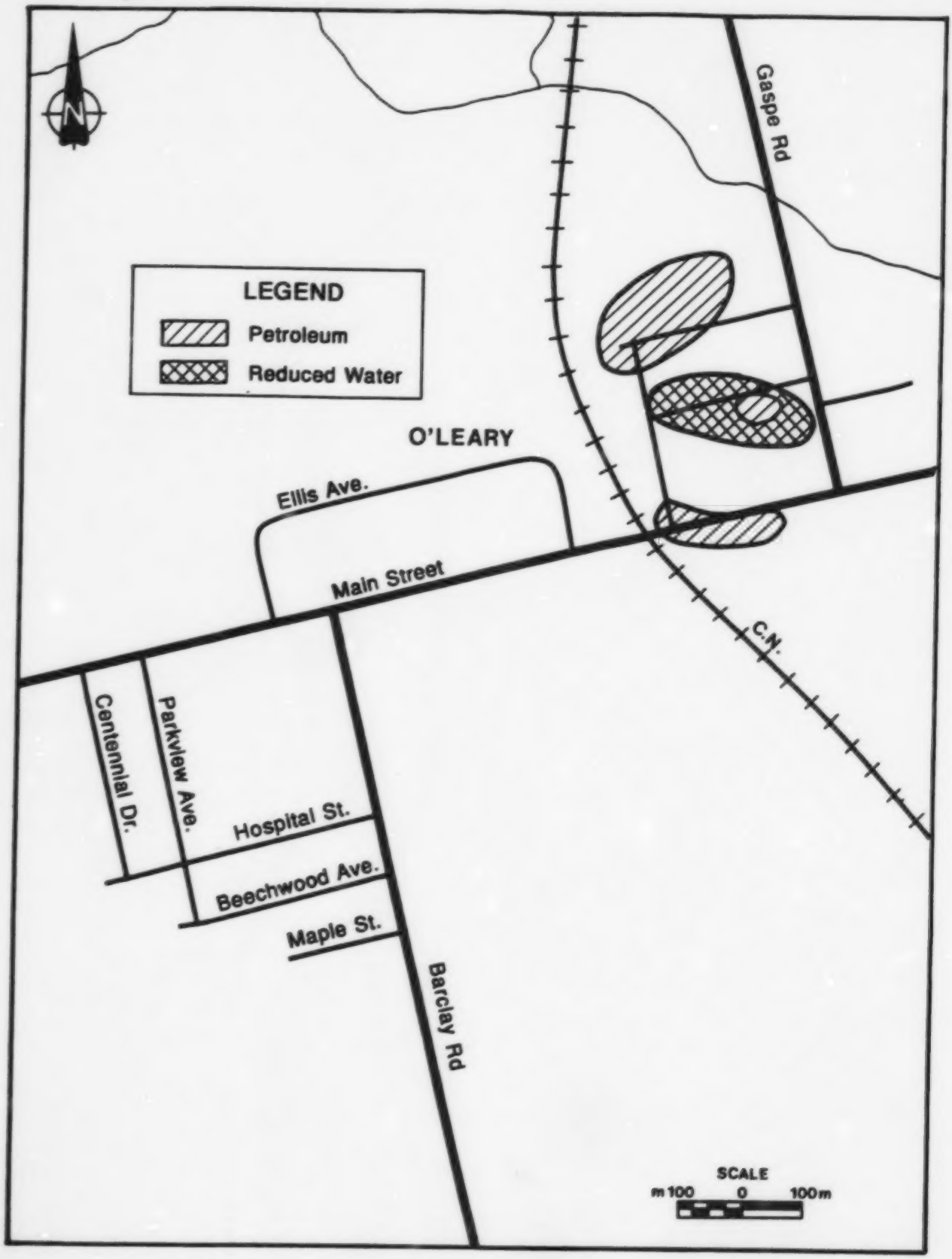
Out of 140 surveys delivered, a response was received from 44 residents. As was expected, information regarding well construction, repair or reconstruction was scant, as many of the wells in this part of the community are relatively old, and residents either could not remember the information or had taken ownership of the property a considerable period of time after the well was constructed.

Information from the responses was highly subjective. What might be considered a serious problem to one resident might go unnoticed by another resident or constitute only a minor inconvenience. Nonetheless, the survey did provide useful information on the general magnitude and areal extent of water quality problems, and provides some insight into the probable causes and potential solutions to the problems in this area of the community. The results of the survey are shown in Table 3.

The results of the survey apply only to the northeastern part of the community. Overall water quality in the community is considerably better than these numbers would indicate. In addition, the response rate for the survey was less than 50 %, and it might be expected that the responses received are somewhat biased toward residents that have had water quality problems. It is anticipated therefore, that the percentage of respondents reporting water problems is higher than if the response rate were closer to 100%.

Of the residents responding, 67% reported that they had no problems and of these approximately two thirds have had their water tested. The remaining third had never noticed any problems with their water and have assumed that their water quality was acceptable.

Figure 10


N
LEGEND
Petroleum
Reduced Water
Gaspe Rd
O'LEARY
Ellis Ave.
Main Street
C.N.
Centennial Dr.
Parkview Ave.
Hospital St.
Beechwood Ave.
Maple St.
Barclay Rd
SCALE
m 100
0
100m

Of the remaining respondents, one third reported having had serious water quality problems, the majority related to petroleum contamination, with occasional complaints of high iron and manganese. The other two thirds who reported problems had experienced minor problems half of which were related to petroleum contamination and half which related to bacterial contamination.

The approximate outline of the areas presently affected by petroleum contamination and reduced water (ie. high iron and Manganese concentrations, taste and odor problems) are indicated on Figure 10. Incidents of bacterial contamination are not systematically distributed throughout the community, and are not shown on the map. It is probable that in most cases these result from poor well construction or faulty sewer lines, rather than any intrinsic charac teristic of the aquifer.

Table 3. Results of Water Quality Survey, north-eastern O'Leary

I	No Water Quality Problems Reported	67%
	a) water analyzed, found acceptable	40%
	b) water not analyzed, no problem suspected	27%
II	Minor or Non - Persistent Water Quality Problems	18%
	a) water problem related to petroleum (since corrected or disappeared)	9%
	b) water problem related to bacteria	9%
III	Serious or Persistent Water Quality Problems	15%
	a) serious or persistent petroleum contamination	13%
	b) serious or persistent problems related to "reduced" water (ie. high iron or manganese concentrations, "swampy odor")	2%

6. Planning Considerations

The provision of adequate supplies of potable water should be an integral part of planning in any community. Not only should the provision of water for current needs be considered, but the future water needs of the community must also be addressed.

6.1 Availability of Groundwater

The investigations carried out under this program indicate that, with the exception of parts of the north eastern portion of the community, adequate supplies of good quality water are being obtained from individual domestic wells.

In the northeastern part of the community, persistent water quality problems of high in iron and manganese concentrations, bacterial contamination, and petroleum contamination continue to occur. Problems of high iron and manganese are a naturally occurring problem for which little can be done except the adoption of point of use treatment devices. Bacterial contamination resulting from faulty sewer lines can be corrected, as can problems where poor well construction allows infiltration of surface water into wells.

Contamination of water supplies by petroleum is a more serious problem which is more difficult and costly to correct (if remediation of the affected aquifers is possible at all.) With this latter point in mind it may be to the community's advantage to consider the provision of central water supply to those areas of the community where, even with improved well construction, experience has shown that it is difficult to assure a supply of potable water from individual wells.

Within the community boundaries, the most favorable location to site such a supply would appear to be the location of the test drilling conducted under this program. While it it is difficult to say at this point, what proportion of the community should be included under such servicing, the results of pump testing indicate that the existing test wells are probably capable of providing a total 8.3 L/sec or 717 m^3/day.

If half of the current residents were to be supplied with central water this would create a demand of approximately 116 m^3/day (1.3 L/sec) with a peak flow requirement of perhaps 4 L/sec), well within the estimated total capacity of the existing test wells.

A point to be considered however, is that approximately 60% of this available water supply is from a single well (test hole OL-1), and if this well should fail, test well OL-2 would have difficulty meeting peak flow requirements. Provision of a third well in the same general location as test hole OL-1 and 2 would provide additional insurance against such events.

Further pump testing, of test well OL-2, which has undergone a limited period of testing, would be advisable before any serious plans for a central water supply were completed. Of particular interest would be the combined effects of pumping both test wells at the same time. It is possible that if both wells were pumped simultaneously for prolonged periods of time, the resulting drawdown from the well field would be sufficient that water service should be provided to houses closest to the well field.

In the western end of the community there appears to be no particular reason why existing on-site water supplies should not continue to provide the water needs of the residents. In the event that it was desired to include these areas in plans for central servicing, it is probable that sufficient quantities of water could be developed in the same area as the existing test wells, either in the same park land or on the adjacent high school property.

When considering any area for the development a water supply which will involve substantial groundwater withdrawals, it is important to ensure that the area under consideration can support the required level of pumping with out creating adverse effects on other water users. This includes the possible effects on other wells in the vicinity as well as any impact on the contribution of groundwater to surface water flows.

In Prince Edward Island surface water divides and groundwater divides are generally thought to coincide (Francis, 1989), allowing the delineation of hydrogeological regimes into systems based on surface watershed extent. The level of groundwater withdrawal possible without adverse impacts to other water users is a function of the areal extent of the watershed contributing water to the well field, and can be based on the amount of available recharge. O'Leary is located in the upper portion of the Trout River watershed, with an area potentially contributing recharge to the O'Leary area of approximately 7.2 km^2. For the purposes of this report it can be assumed that up to 50% of the available recharge may be safely withdrawn without adversely affecting stream flows in the area. Typical recharge rates on the Island are in the range of 35 % of annual precipitation which averages 1100 mm. Using these assumptions the amount of water potentially available at the test site is estimated to be in the range of 40 L/sec or over 3,700 m^3/day, far in excess of the communities requirements in the forseeable future.

6.2 Groundwater protection strategies

The importance of groundwater resources to the people and industries of Island communities is well recognized. The importance of implementing sound, far-sighted strategies aimed at protecting this valuable resource is less frequently recognized. The following discussion attempts to provide some focus to the issue, by presenting some possible approaches to the development of a comprehensive groundwater protection strategy.

The issue of groundwater protection can be separated into two components: specific recommendations for the protection of central water supply wells or well fields; and general considerations pertinent to the establishment and operation of on - site water supplies and protection and preservation of groundwater resources in general.

It is worth commenting at this point that even if a community has no intention of developing a central water supply in the foreseeable future (and indeed, such a consideration may not be appropriate to the development plans of a community), it is highly desirable to consider this possibility, and to be aware of the requirements and constraints involved in the development of a

central water supply. This exercise ideally would involve the identification suitable locations for the development of such a supply and appropriate strategies to protect the resource for future use.

Well field protection

Unlike the processes that lead to the contamination of surface water bodies, the degradation of groundwater resources is often not directly observable, and consequently more difficult to predict, correct and avoid. Once contaminants have been introduced into a groundwater system, their migration and fate is governed by a complex series of reactions and processes which depend on a number of parameters which may be only poorly documented . Consequently the prediction of the consequences of the introduction of contaminants into a groundwater reservoir in the vicinity of wells supplying a water supply system requires a number of approximations and assumptions of varying validity.

A number of approaches have been developed to provide varying degrees of protection to the wells supplying central water supply systems. In general, the object of these strategies is to designate a given area around the well or well field in which activities having the potential to contaminate the water supply are regulated or prohibited.

"The major parameters in developing groundwater protection strategies for municipal water wells are legal, socio-economic and hydrogeological" (Gregory, 1988), In this report suggested protective strategies are based primarily on hydrogeological parameters. It is recognized that the modification of these strategies in light of socio-economic factors is an inevitable and desirable aspect of the development of appropriate strategies for individual communities.

Typical methods by which the size of a protective zone can be determined are:

1) Radius of influence - a zone based on the drawdown characteristics of the well

2) Delay time zone - a zone based on the time potential contaminants would take to travel towards a well in a given time period under the prevailing hydrogeological conditions.

3) Recharge Area - a zone which outlines the areal extent of land which contributes water to the well or well field under the influence of pumping and the natural hydraulic gradient.

These methods have the appeal that they can be based on the actual characteristics of the aquifer, and may thus be justified to some extent on the basis of their scientific foundations. It should be noted at the outset however, that rarely are the aquifer characteristics sufficiently well known that the suggested protection zones provide an absolute guarantee of protection. Nonetheless, these approaches can help in developing rational water management policies, which can be refined and improved as additional information or insight into actual field condi-

tions are accumulated.

Each of the approaches described above has strengths and weaknesses, and it is perhaps advisable to develop well field protection strategies which incorporate the most appropriate aspects of each approach. The following considerations may form the basis of such a strategy.

Although the community might chose to service only those portions of the area which currently have water quality problems, for the purposes of establishing the appropriate well field protection measures, it is important to consider the ultimate, future development of the well field. For the purposes of this exercise, it will be assumed that the entire community is to be serviced by a central water supply, and the average daily pumping rate is 2.6 L/sec, with a peak flow requirement of around 7.9 L/sec. This should be adequate to supply residential and small scale commercial requirements. This does not include provision for additional development in the future, however it will give an appreciation of the scale of the types of measures which would be required to reasonably protect a well field. The approximate boundaries for each of these "well field protection zones" are indicated on Figure 11.

Radius of influence:

Providing that the relevant aquifer parameters are sufficiently well known and the response of the aquifer to pumping is monitored for a sufficiently long period of time, it is possible to determine the areal extent of the cone of depression of a well under pumping conditions.

This "cone of depression" is effectively the area from which the the well withdraws its water. Theoretically, it expands in size as pumping starts until at some point an equilibrium is reached where the rate of recharge to the aquifer and the rate of withdrawal of water from the aquifer are balanced, at which point it ceases to expand any further. The diameter of this "stabilized" cone of depression therefor would constitute the protective zone, within which activities with the potential to pollute the groundwater would be restricted or prohibited.

There are a couple of short-comings with this approach as it may be applied to O'Leary. First, the duration of the pump tests conducted under this program is relatively short, and it would be difficult to determine if the cone of depression due to the pumping has actually reached equilibrium.

Because large scale recharge of aquifers on P.E.I. usually only occurs twice a year (in the spring after snowmelt and usually in mid fall), monitoring of water levels over a considerable period of time would be required to determine the long-term effect of pumping on the aquifer and the probable maximum area of influence of the well. Furthermore the actual size of such a zone would be expected to expand in size as the time since the last recharge event increases and then contract in response to the next major recharge event.

In addition, the notion of the "radius of influence" does not take into account the migration of

groundwater in response to the natural hydraulic gradient (ie. the flow of groundwater towards the well independent of pumping). In the area around O'Leary however, it is expected that the natural hydraulic gradient is fairly low, and these concerns can probably be ignored.

In spite of the short comings of this approach it does provide some rational basis on which to base some sort of protective strategy. As noted above the duration of the pumping tests conducted are too short to identify the steady state or equilibrium characteristics of the area of influence of these wells. An approximation of the extent of this area can be made however, as the radius at which the influence of pumping difficult to distinguish from the natural hydraulic gradient. For the two test wells constructed under these investigations, such a point is reached at a radius of approximately 75 m. (During the constant rate test, pumping at 4.9 L/sec resulted in a considerably larger cone of depression, as indicated by the drawdown recorded in the observation well during the test, however this was at a considerably greater pumping rate than the expected average daily flow conditions).

Within this area it would be desirable to prohibit any residential, commercial or industrial development although some forms of recreational activities could be compatible with the development of a water supply. While the existing level of development may make this goal impossible to meet, restrictions could be placed on new development in the area described.

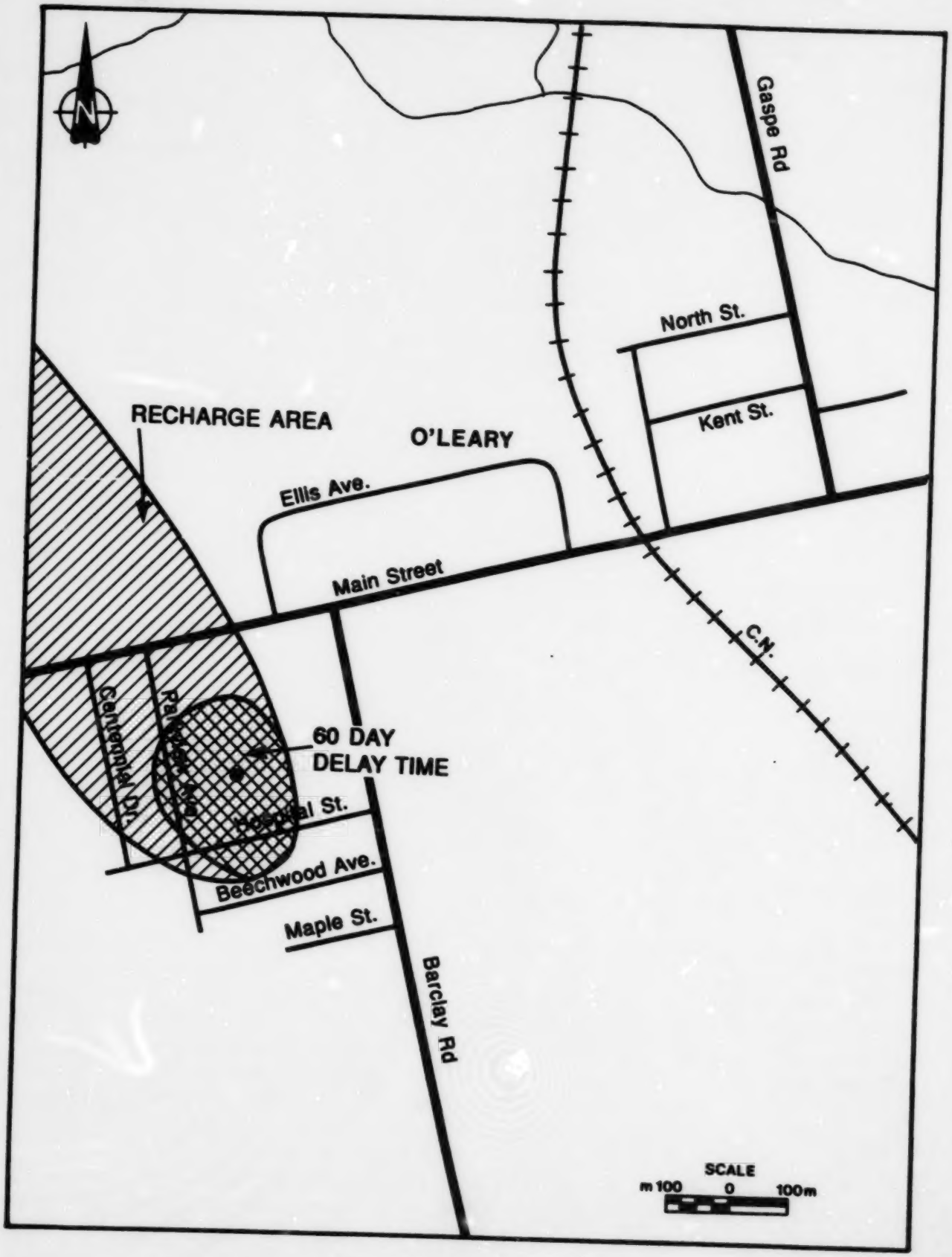
60 Day Delay Time Zone

The rate at which a potential contaminant can travel towards a well is a function of a number of factors including the nature of the aquifer materials, the natural hydraulic gradient and the hydraulic gradient induced by pumping of the well or wells.

As might be expected, the higher the pumping rate, the more rapidly a contaminant will travel towards the well, and the larger the radius of the delay time zone around a well or well field must be to provide the protection time.

A convenient starting point would be to identify a 60 day delay time zone . A zone of this size should provide protection against most pathogenic organisms (60 days is the maximum most pathogenic organisms are believed to survive in groundwater), and would also provide time that an alternate well location could be developed if a particularly serious incidence of contamination threatened the water supply. Thus if for instance a spill of hazardous material occurred at the edge of this zone, the community would have approximately 60 days in which to take what ever remedial actions were possible before the contaminant would be expected to reach the well head. Based on an average pumping rate of 3 L/sec, the aquifer parameters derived from pump testing activities in the O'Leary area, and an effective porosity of 1%, estimates have been made for the distance that a potential contaminant would move toward a potential production well in a given period of time.

Figure 11


N
Gaspe Rd
North St.
Kent St.
RECHARGE AREA
O'LEARY
Ellis Ave.
Main Street
C.N.
60 DAY
DELAY TIME
Centennial Dr.
Beechwood Ave.
Maple St.
Barclay Rd
SCALE
m 100 0 100m

For a 60 day delay time zone, a circular area with a radius of 100 m would be required if the effects of the natural hydraulic gradient are ignored. If the natural gradient (assumed to be approximately 1%) is considered, the delay time zone becomes ellipsoid in shape, extending further in the upslope direction (to the northwest) and being some what shortened in the down slope direction. In this case the delay time zone would be lengthened to approximately 335 m to the northwest of the well (up slope direction) and shortened to about 75 m to the southeast (downslope direction). While the "upslope" extent of this zone may seem rather extreme, it should be noted that even without any pumping, groundwater would travel a distance of approximately 260 m under the influence of the natural hydraulic gradient of 1% in a period of 60 days.

Within the inner 60 day zone certain types of activities should be restricted or prohibited. Since the community is already serviced by sewer, there should be no concern over on-site sewage disposal. However particular care should be exercised in ensuring sewer line integrity in the area. The storage or application or disposal of road salt, agricultural chemicals or other potentially hazardous substances, including petroleum products, should be prohibited or restricted from this area. In addition, developments in this area should be subjected to an environmental impact assessment, to determine the probable impact on the groundwater resources in the area.

Recharge Area :

The recharge area for a well field describes all the area from which groundwater is expected to flow towards the well or well field either under the existing natural hydraulic gradient or from the effects of pumping. In the case of the test drilling site investigated under this study this would encompass a significant portion of the area of the community to the northwest of the site. Within this area, major development proposals, or proposed land use changes should be subjected to an environmental impact assessment.

7. Conclusions and Recommendations

The investigations conducted as a part of this study indicate that the natural quantity and quality of groundwater resources in much of the community of O'Leary are generally good and sufficient to meet the community's needs. However a significant portion of this area has historically experienced rather severe water quality problems. Some of these problems are manmade, such as petroleum contamination, high nitrate concentrations and bacterial contamination, while others appear to be primarily of natural origin. Problems such as high iron and manganese concentrations are generally associated with older, shallower wells, and may be prevented by more modern well construction techniques.

The test drilling program conducted under this project has identified a suitable location for the development of a central water supply, which would provide a sufficient quantity of water to

meet the communities needs, as well as sufficient space to provide for the protection of groundwater quality. The existing test wells are estimated to have a combined capacity of 8.3 L/sec (717 m^3/day), sufficient capacity to supply the water needs of the existing population. In addition,the test site as sufficient additional room to construct additional wells if necessary.

In light of the serious water quality problems in the north-eastern part of the community, and the availability of an alternate source of water within the community boundaries, the community should give consideration to developing this source of supply to service at least the portions of the community which have experienced water quality problems. The community should also take steps to implement well field protection measures, through appropriate zoning by-laws, to ensure the future integrity of groundwater resources in this area.

References:

Francis, R.M., 1981: Hydrogeological properties of a fractured porous aquifer, Winter River Basin, Prince Edward Island; Unpublished Msc. Thesis, University of Waterloo

Francis, R.M., 1989: Hydrogeology of the Winter River Basin, Prince Edward Island Department of the Environment

Gregory, A., 1988: Inventory and review of New Brunswick municipal groundwater supply areas, prepared for Environment Canada, Consevation and Protection, Atlantic Region

Health and Welfare Canada, 1989: Guidelines for Canadian Drinking Water Quality, Dept. of Supply and Services, Ottawa

Jacques, Whitford and Associates Limited, in preparation: Salt Water Well Study, Prince Edward Island, prepared for the P.E.I. Dept. of Industry

Jardine, D.J., 1976: Groundwater Contamination in the O'Leary Road - North Street - Kent Street Area, O'Leary, P.E.I., Unpublished report , P.E.I. Dept. of the Environment

MacDougall and Veer, 1981: Soils of Prince Edward Island, Agriculture Canada, Charlottetown, Prince Edward Island

Prest, V.K.,1973: Surficial Deposits of Prince Edward Island; Geol. Surv. Can., Dept. of Energy Mines and Resources, Map 1366 A

Robinson, J.W., 1986: Guidelines for aquifer pumping tests, Water Resources Division, Newfoundland Department of the Environment

Van de Poll, H.W., 1981 Geology of Prince Edward Island; Prince Edward Island Department of Tourism, Industry and Energy

APPENDIX I

WATER WELL DATA

APPENDIX II
Water Quality Analyses
O'LEARY

Name&Date		Easting/Northing	Parameters																
			Ca	Mg	Na	K	Hard.	Alk.	Cl	SO4	P	NO3	NH4	pH	Fe (T)	Fe (D)	Mn	Cu	Pb	Zn
M. Campbell	800704		34.0	8.00	5.5	1.45		136	9	< 5	0.10	1.4	< 0.2	8.2		< 0.1	< 0.02	0.02	< 0.1	0.60
Co-operative	800704		30.0	7.00	6.0	0.90		89	11	11	0.09	2.1	< 0.2	7.9		< 0.1	< 0.02	0.05	< 0.1	0.35
Corinthian Lodge	860522	406800/5173250	57.0	13.94	8.8	1.72	200.9	168	35		0.12	< 0.2		7.2	< 0.1	< 0.1	0.16	0.03	< 0.1	0.47
Alfred Dennis	850612	405850/5173300	80.5	8.05	29.0	0.91	251.8	262	60		0.10	2.4		7.4	< 0.1	< 0.1	< 0.02	0.04	< 0.1	0.44
Allison Ellis	851106	406300/5173450	44.2	16.92	7.9	1.59	181.3	172	19		0.04	< 0.2		7.0	0.5	< 0.1	0.51	0.04	< 0.1	0.11
Kent Ellis	850709	406470/5173386	60.9	17.65	9.3	1.42	227.0	206	30		0.12	0.7		7.3	< 0.1	< 0.1	0.91	0.12	< 0.1	0.29
Warren Ellis	840327	406460/5173200	64.5	18.03	10.2	1.33	214.0	224	31		0.12	2.8		7.7	< 0.1	< 0.1	0.75	0.05	< 0.1	0.02
Warren Ellis	840619	406460/5173200	76.0	0.19	9.9	1.46	193.5	239	34		0.06	< 0.2		7.2	< 0.1	< 0.1	1.06	< 0.02	< 0.1	0.51
Warren Ellis	871222	406460/5173200	25.6	13.72	6.7	2.81	120.6	123	6		0.39	0.5		7.8	0.9	< 0.1	< 0.02	< 0.02	< 0.1	< 0.02
Jim Gallant	870105		58.9	24.33	13.5	2.21	252.4	235	29		0.38	0.7		7.2	0.4	< 0.1	1.35	< 0.02	< 0.1	0.05
Wesley Hubert	860307	406500/5173400	44.5	14.32	9.5	0.96	172.5	212	36		0.10	< 0.2		6.9	3.0	< 0.1	1.17	< 0.02	< 0.1	0.11
Lidstone's S.S.	870303	406400/5173200	131.7	34.42	61.0	2.03	433.6	325	90		0.10	12.5		6.6	1.5	< 0.1	0.10	0.40	< 0.1	2.54
Angus MacBain	780412	406700/5173450	50.0	12.00	13.8	3.10	180.0	128	28		0.04	6.0	0.2	6.9	0.1	< 0.1	0.06	< 0.02	< 0.1	0.08
Edward MacDonald	761118	406350/5173650	67.0	31.80	9.0	1.86	306.0	177	50		0.08	14.0	< 0.2	8.1		< 0.1	0.03	< 0.02	< 0.1	< 0.02
Helen MacDonald	861229		18.6	5.52	8.8	3.03	72.8	16	26		0.04	8.0		6.4	0.3	< 0.1	0.04	0.03	< 0.1	0.59
Keir MacDonald	860819	406400/5173400	84.7	21.55	12.0	1.85	232.4	209	35		0.15	< 0.2		7.1	1.7	< 0.1	0.83	< 0.02	< 0.1	0.38
D. MacEachern	820706	406470/5173360	77.0	17.60	11.0	1.40	265.0	207	37	30	0.10	< 0.2	< 0.1	7.2	0.1	< 0.1	1.15	0.09	< 0.1	1.23
H. MacWilliams	870421	406500/5173300	48.1	12.79	11.9	3.46	178.1	173	29		0.06	1.5		6.9	0.4	< 0.1	0.26	0.12	< 0.1	0.15
Jean Pate	871020		50.5	19.70	10.0	2.29	210.6	229	29		0.12	< 0.2		7.4	1.0	< 0.1	0.87	0.03	< 0.1	1.09
Marcia Pate	780412	406500/5173250	46.0	7.30	14.0	5.20	160.0	124	21		0.04	1.1	0.2	6.9	0.5	< 0.1	0.20	< 0.02	< 0.1	0.07
Marcia Pate	850730	406500/5173250	47.1	9.47	13.3	4.50	158.6	152	23		0.10	1.3		7.3	0.3	< 0.1	0.20	0.07	< 0.1	0.93
B. Phillips	851113	406361/5173450	76.2	30.26	20.6	1.27	279.4	265	45		0.17	1.0		7.2	< 0.1	< 0.1	< 0.02	< 0.02	< 0.1	0.38
Radio Shack	800704		36.0	8.50	7.0	0.90		119	15	13	0.06	2.1	< 0.2	7.5		< 0.1	0.06	0.10	< 0.1	2.00
Old Sandpile	800501		42.5	5.50	130.0	4.50		66	1900		0.02	0.2	< 0.2	8.0			0.28	0.05	< 0.1	1.90
Scotia Bank	800704		42.0	7.50	8.5	0.90		113	21	< 5	0.06	2.7	< 0.2	7.5		< 0.1	< 0.02	0.15	< 0.1	
Jeff Smallman	851113	406350/5173450	63.9	18.01	17.4	1.71	234.0	253	40		0.14	< 0.2		7.1	< 0.1	< 0.1	< 0.02	< 0.02	< 0.1	0.10
Herbie Strang	870616		133.3	16.24	20.0	1.01	400.0	270	60		0.10	1.1		6.8	< 0.1	< 0.1	< 0.02	0.06	< 0.1	0.03
Robert Turner	761221	406400/5173300	40.0	7.00	20.0	1.40		91	20	40	0.08	1.8	< 0.2	7.2		< 0.1	< 0.02	< 0.02	< 0.1	0.05
Hollis Wills	871222		57.4	26.45	15.1	2.11	253.1	178	60		0.37	3.5		7.2	2.7	< 0.1	0.32	< 0.02	< 0.1	0.12
ADL Plant	860331	406500/5173400	76.0	33.42	14.8	7.00	339.0	273	90		0.06	< 0.2		7.9	3.4	< 0.1	6.05	0.02	< 0.1	0.29
ADL Plant	860411	406500/5173400	76.6	34.49	11.9	3.42	333.9	163	100		0.04	14.0		7.5	0.2	< 0.1	0.16	< 0.02	< 0.1	0.14
ADL Plant	860522	406500/5173400	66.0	22.99	9.4	2.70	258.0	141	75		0.12	9.0		7.4	< 0.1	< 0.1	0.12	0.03	< 0.1	0.46
ADL Plant (raw)	861029	406500/5173400	61.5	36.28	11.7		302.9													

Name&Date		Easting/Northing	Ca	Mg	Na	K	Hard.	Alk.	Cl	SO4	P	NO3	NH4	pH	Fe (T)	Fe (D)	Mn	Cu	Pb	Zn
ADL Plant (tr.)	861029	406500/5173400	54.5	37.86	11.9	3.08	292.8	173	70		0.07	11.0		7.4	< 0.1	< 0.1	0.21	0.05	< 0.1	0.20
ADL Plant	871027	406500/5173400	26.2	13.26	7.5	2.48	120.2	160	9		0.15	0.8		8.0	< 0.1	< 0.1	< 0.02	< 0.02	< 0.1	< 0.02
Hospital	810722	405720/5172720	40.0	14.90	8.0	1.20	161.0	123	24	8	0.08	2.1	< 0.1	7.9	< 0.1	< 0.1	0.02	0.25	< 0.1	0.74
Hospital	840403	405720/5172720	30.4	16.34	8.8	1.16	143.5	136	25		0.16	1.7		7.9	< 0.1	< 0.1	< 0.02	< 0.02	< 0.1	0.07
Hospital	841009	405720/5172720	29.9	14.36	8.9	1.16	134.8	130	31		0.10	2.6		7.6	< 0.1	< 0.1	< 0.02	0.03	< 0.1	0.53
Hospital	861124	405720/5172720	31.9	16.45	11.1	1.49	156.1	146	38		0.07	2.3		8.1	0.2	< 0.1	< 0.02	< 0.02	< 0.1	0.20
Hospital	880202	405720/5172720	31.3	16.06	12.1	1.34	144.5	136	40		0.17	2.3		7.5	0.2	< 0.1	0.04	0.04	< 0.1	< 0.02
Elementary Sch.	820610	405770/5172790	12.0	11.80	9.0	2.10	78.0	139	16	13	0.04	1.8	< 0.1	7.2	0.4	< 0.1	0.15	1.38	< 0.1	1.49
Elementary Sch.	840403	405770/5172790	30.7	17.27	8.8	1.63	148.5	150	15		0.16	1.7		7.0	< 0.1	< 0.1	0.13	0.14	< 0.1	0.20
Elementary Sch.	850212	405770/5172790	33.9	18.52	8.3	1.58	162.5	153	17		0.10	1.8		7.7	< 0.1	< 0.1	0.11	0.25	< 0.1	0.81
Elementary Sch.	870303	405770/5172790	39.9	19.10	9.0	1.47	179.1	155	17		0.08	1.7		7.5	0.3	< 0.1	0.14	0.67	< 0.1	0.28
Sr Clt. A (C)	841213	405440/5172830	33.4	12.71	6.0		135.7													
Sr Clt. A (H)	841213	405440/5172830	6.6	1.08	71.0		20.9													
Sr Clt. B (C)	841213	405440/5172830	31.6	13.66	7.6		135.1													
Sr Clt. B (H)	841213	405440/5172830	10.5	1.35	75.0		31.8													
Sr Clt. C (C)	841213	405440/5172830	29.0	12.62	6.1		125.2													
Sr Clt. C (H)	841213	405440/5172830	4.8	2.44	67.0		22.0													
Sr Clt. A (H)	850806	405440/5172830	1.8	0.33	73.0	0.28	6.1	109	14		0.10	2.5		7.7	< 0.1	< 0.1	< 0.02	< 0.02	< 0.1	0.03
Sr Clt. B (H)	850806	405440/5172830	1.1	0.45	74.0	0.22	5.0	104	18		0.08	2.8		7.1	< 0.1	< 0.1	< 0.02	0.29	< 0.1	0.15
Sr Clt. C (H)	850806	405440/5172830	5.5	0.45	78.0	0.54	16.5	105	15		0.12	3.0		7.8	< 0.1	< 0.1	< 0.02	0.05	< 0.1	0.45
Sr Clt. B (C)	860501	405440/5172830	30.6	14.91	7.7	1.05	138.4	105	26		0.10	1.9		7.1	< 0.1	< 0.1	< 0.02	0.14	< 0.1	0.28
Sr Clt. B (H)	860501	405440/5172830	3.9	0.63	69.4		12.3													
Sr Clt. A (C)	870303	405440/5172830	33.8	13.96	10.3	1.60	142.7	120	13		0.08	2.6		7.8	< 0.1	< 0.1	< 0.02	0.07	< 0.1	0.44
Sr Clt. A (H)	870303	405440/5172830	8.4	1.78	87.0		28.3													
Sr Clt. B (C)	870303	405440/5172830	32.6	16.42	8.6	0.96	149.3	120	21		0.08	3.1		7.8	< 0.1	< 0.1	< 0.02	0.38	< 0.1	0.08
Sr Clt. B (H)	870303	405440/5172830	4.8	2.08	91.0		20.8													
Sr Clt. C (C)	870303	405440/5172830	32.3	14.46	7.4	1.14	140.6	117	16		0.08	3.2		7.8	< 0.1	< 0.1	< 0.02	0.17	< 0.1	0.17
Sr Clt. C (H)	870303	405440/5172830	0.3	0.40	92.0		2.4													
		CDWS							250	500		10.0		6.5-8.5	0.3		0.05	1.00	0.05	5.00

APPENDIX I
O'LEARY

WATER WELL DATA

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (lgpm)	Time (min)	Geology	Aquifers (Water Occurrences)
Mclesac, Kenneth	710707	404500	5172700		100		26	8	15	0-6 Clay 6-55 Shale, clay, sandstone	27 30 51 54
Ramsaye Washed Gvl	831202	404500	5172800	153	100	35	104	8	10	0-18 Clay 18-153 Soft/hard sandstone, claysand	
Comet Const.	810116	404600	5172800	62	100	30	32	8	7	0-2 Clay till 2-62 Claysand, sandstone	52 55 60 63
Swast, Frankie	710823	404600	5172700		120		21	8	15	0-10 Clay 10-57 Shale, sandstone	29 32 51 54
MacMillan, Herman	770923	404500	5172800	65	110	15	36	7	7	0-65 Sandstone, claysand	58 61
Dennis, Dale	710510	405020	5172880	62	80	14	18	6		0-10 Clay 10-62 Sandstone, claysand	
Adams, Gerald	840829	405100	5172800	80	100	18	40	10	10	0-2 Clay 2-80 Claysand, sand, sandstone	38 41 67 70 78 79
Adams, Gerald	840826	405100	5172800	80	100	15	40	10	10	0-2 Clay 2-80 Claysand, sanstone	37 40 68 71 78 80
Adams, Gerald	840827	405100	5172840	80	100	20	40	10	10	0-2 Clay 2-80 Sand, claysand, sandstone	38 41 70 73 78 80
Adams, Gerald	840828	405130	5172800	80	100	15	40	10	10	0-2 Clay 2-80 Sand, claysand, sandstone	72 75 85 88
Adams, Gerald	840829	405150	5172800	110	100	25	40	10	10		74 77 100 103
Flamino, Nick	720711	405200	5172500		110	8	21	8	15	0-6 Clay 6-63 Shale, sandstone	28 31 55 58
Palmer, Carol	770628	405300	5172805	65	120	15	38	7	7	0-65 Claysand, sandstone	59 62
Clements, Jim	770516	405200	5172800	70	120	14	31	8	15	0-9 Clay till 9-70 Soft clay, sandstone, claysand	32 36 63 68
McDougal, Heath	780815	405250	5172850	65	120	15	33	10	8	0-65 Sandstone, claysand	62 65
Ellis, Mrs. Wanda	750922	405300	5172320	70	25	15	28	9	5	0-22 Till 22-70 Sand, clay, MDGR, sandstone	30 67
Ellis, Denton	850906	405300	5172500	55	100	25	34			0-4 Clay and sand 4-55 Sandstone and claystone	41 44 53 55

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)
Ellis, Warren	800000	405300	5172900	55	100	28	32	5	5	0-3 Clay till 3-55 Sandstone, claysand	30 33 38 41 54 57
MacCormick, Shirley	750918	405320	5172310		100	17	25	10	5	0-24 Till 24-71 Sandstone	32 35 67 70
McDonald, Donald	860117	405400	5170600	50	75	26	30			0-2 Clay 2-50 Sandstone and claystone	40 43 48 50
Manse, Nigmore	800722	405400	5172800	75	100	19	32	12	10	0-9 Sandy till 9-75 Sandstone, shale, clay, claysand	35 40 65 70
Smallman, Elwood	710510	405400	5172900	45	80	5	21	10		0-18 Clay 18-45 Hard sandstone	
Dunville, Otwood	750623	405420	5172799	70	100		22	8	4	0-19 Till 19-70 Clay, sandstone	35 38 65 68
Rayner, P+H	801202	405450	5172650	90	112	15	44	8	7	0-7 Till 7-90 Claysand, sandstone	53 56 82 85
Bagiole, James	700413	405500	5172500	110		40	80	6		0-14 Clay 14-110 Sandstone, claysand	
Campbell, Clean	700524	405500	517250	84		37	54	5		0-84 Clay, sandstone, claysand	
O'Leary Fire Hall	700000	405500	5172500	157		17	45	20	20	0-12 Clay 12-157 Frod sandstone, clay, hard sandstone	85 90 130 133 148 150
MacAusland	711202	405500	5173100	73	125	23	42	8	15	0-15 Clay 15-73 Shale, clay, sandstone	54 57 86 89
MacDonald, Gary	751008	405500	5173400	70	125	15	28	8	15	0-14 Clay till 14-70 Fractured sandstone, sandstone	60 65
MacKay, Neil	711013	405600	5172100		100	30	49	6		0-70 Claysand, sandstone	
O'Leary Rink	730610	405600	3172900	90	100	19	43	10	10	0-40 Clay till, clay, sandstone 40-90 Sandstone, clay	80 85 75 85
MacMillan, Andrew	800619	405600	5173000	70	100	20	39.5	8	7	0-4 Till 4-70 Claysand, sandstone	65 68
McKinnon, E. G.	711018	405650	5172650		100	20	38	6		0-40 Claysand, limesand 40-72 Claysand, sandstone	
Barlow, George	780919	405700	5172500	58	100	30	25	5	5	0-7 Sand, clay till 7-58 Sandstone, sand, claysand	33 36 54 59

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)					
MacDougall	720617	405700	5172800		110	14	21	8	15	0-19 Shale 19-62 Sandstone	30	33	57	60		
Campbell, Maclean	710524	405700	5172700	84	86	37	54	5	5	0-15 Clay 15-84 Sandstone, claysand						
Macisaac, Mary	720602	405700	5172800		115	12	23	8	15	0-20 Clay, shale 20-61 Sandstone	27	30	57	60		
Harris, Hoseman	650403	405700	5172900	85	100	30	60			0-20 Clay, sand and claystone 20-85 Sandstone and claystone	70	73	84	85		
North Star Constr.	840805	405700	5173100	60	100	25	30	10	5	0-2 Clay 2-60 Sandstone, claysand	28	31	45	48	58	60
Sweet, Claire	720524	405700	5173300		110	8	21	8	15	0-18 Shale 18-60 Sandstone	25	28	57	60		
O'Leary Med. Center	701024	405770	5172570	85	110	20	45	6	10	0-15 Clay 15-85 Sandstone, claysand						
Worth, Brian	780518	405800	5172500	85	100	16	43	10	10	0-16 Fractured clay, till, sandstone 16-85 Hard sandstone, claysand	45	55	80	85		
Belangh, Crest	780612	405800	5172600	88	100	24	43	9	10	0-9 Clay till 9-88 Claysand, sandstone	45	50	75	85		
Phillips, Waldo	771014	405800	5172800	73	120	25	31	8	10	0-8 Clay till 8-73 Sandstone, claysand	35	40	60	70		
Gallant, Wesley	810707	405800	5172900	105	100	29	75	10	10	0-18 Clay till, sandstone 18-105 Sandstone, claysand, clay	90	100				
Campbell, Isabel	851107	405800	5173100	60	100	16	31			0-18 Clay, sand and claystone 18-60 Sandstone and claystone	40	43	48	51		
Dennis, Wilfred	711202	405800	5173300	70		21	28			0-14 Clay 14-70 Shale, sandstone	42	45	68	69		
Boulter, Miles	780830	405802	5172292	70		15	44	8	10	0-11 Clay till 11-70 CNTD sandstone, claysand, sandstone	60	63				
Matheson, Donald	770525	405850	5172800	70	135	15	54	8	8	0-5 Till 5-70 Claysand, sandstone	69	70				
O'Halloran, Danny	800500	405900	5171050	68	60	18	38	6	10	0-8 Till 8-68 Clay, shale, sandstone	40	43	62	65		
Salter, John	800527	405900	5172200	60	80		30	8	10	0-22 Clay, BLDR, till 22-60 Shale, sandstone	32	35	54	57		

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)
Bostes, Arnold	830203	405900	5172500	90	100	22	59	15	10	0-9 Clay till 9-90 Clay, frcd sandstone, claysand, sandstone	65 70 80 85
Vet Clinic	761125	405900	5172750	177	110	20	43	30	30	0-40 Clay, sandstone, till 40-177 Sandstone, claysand	55 60 165 170
ATO Property Ltd.	831212	405900	5173100	70	100	25	46		5	0-2 Clay 2-70 Sand, claysand, sandstone	60 63 68 70
Liquor Store	870607	405900	5173100	165	100	19	103	30	120	0-17 Clayey till and clay 17-165 Sandstone and claystone	110 115 150 160
Shea, Bernard	820812	405900	5173200	60	100	20	35	10	10	0-16 Clay, till 16-60 Clay, claysand, sandstone	45 55
Low Rental Housing	870731	405900	5173340	60	100	20	46	8	10	0-15 Clay 15-60 Sandstone	
Low Rental Housing	870730	405900	5173450	60	100	20	45	8	10	0-10 Clay 10-60 Sandstone	
Low Rental Housing	870730	405900	5173360	60	100	20	45	8	10	0-15 Clay 15-60 Sandstone	
Low Rental Housing	870731	405900	5173400	60	100	20	45	8	10	0-10 Clay 10-60 Sandstone	
Dunville, Etsel	750628	405990	5172500		100	16	22	10	4	0-20 Till 20-63 Sandstone	25 28 60 63
PEILCC	750919	406100	5173290		100	18	28	10	10	0-24 Till 24-72 Clay, sandstone	31 34 66 71
O'Leary Legion	800107	406100	5173300	58	100		31	5		0-10 Sand, claysand 10-58 Hard sandstone, sandstone, claysand	40 43 57 60
Stewart, Allain	791221	406100	5173400	65	100	43	28	5	7	0-2 Clay till 2-65 Sandstone, claysand	53 58 63 68
O'Leary Produce Coop	810604	406100	5173400	105	100	17	43	25	10	0-10 Clay till 10-105 Sandstone, clay, claysand	80 90 90 100
Low Rental Housing	740403	406103	5173392		120	22	32	10	60	0-7 Clay 7-106 Fractured claysand, clay, sandstone	35 80 85 90
Low Rental Housing	740405	406103	5173392		110	18	32	10	60	0-9 Clay 9-103 Fractured claysand, clay, sandstone	35 80 85 90
Low Rental Housing	740410	406199	5173395		110		37	10	60	0-9 Clay 9-103 Fractured claysand, clay, sandstone	35 55 80 95

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)
Low Rental Housing	740410	408189	5173386		110	17	34	10	60	0-8 Clay 8-105 Fractured claysand, clay, sandstone	35 60 85 95
O'Leary Coop Whse	770921	408200	5173400	135	100	25	43	15	10	0-20 Clay till, clay sandstone 20-115 Claysand, sandstone	50 55 100 110
Imperial Oil Plant	820519	408200	5073460	110	100	50	75	8	7	0-5 Till 5-110 Claysand, sandstone	90 93 104 107
Dumill, Charles	780906	408250	5173350	110	100	50	59	7	7	0-4 Till 4-110 Claysand, sandstone	108 109
Ellis, Garfield	770824	408300	5173100	87	105	15	22	8	10	0-12 Fractured clay, sandstone 12-87 Claysand, sandstone, clay	25 30 50 55
O'Leary Fire Hall	700920	408300	5173000	157	105	17	45	20	20	0-157 Frdr hard sandstone, clay	55 60 130 133 148 150
Johnson, Hillard	860508	408300	5173300	97	100	25	58			0-15 Sand and claystone 15-97 Sandstone and claystone	83 88 95 97
Low Rental Housing	740409	408300	5173400		100	17.5	33	10	60	0-19 Clay, shale 19-105 Sandstone, shale, clay	
Milligan, Lillian	780131	408300	5173500	70	100	20	28	6	30	0-20 Clay till 20-70 Hard/soft sandstone	45 48
Texaco Canada Ltd.	700828	408400	5173180	128	100	30	95	6	5	0-128 Sandstone, claysand	
Gorlli, Keith	770524	408400	5173350	95	100	20	83	8	8	0-5 Till 5-95 Claysand, sandstone	90 93
Kirev, Ivan	800731	408400	5173300	120	100	23	83	12	10	0-16 Clay, till, shale 16-120 Sandstone, claysand	90 95 110 115
Cooke, Hillis	770517	408400	5173400	100	100	20	63	6	8	0-8 Till 8-100 Sandstone, claysand	90 93
Lions Hall	781130	408400	5173500	122	100	20	92	8	15	0-18 Till 18-122 Sandstone, claysand	110 115
Ellis, Warren	840906	408400	5173500	100	100	25	60	5	10	0-2 Clay 2-100 Claysand, sand, sandstone	75 78 98 100
Baglole, James	710512	408480	5173380	72	100	18	40	6		0-20 Clay 20-72 Claysand, sandstone	
Ball & MacRae	720801	408500	5173200		100	13	37	8	15	0-4 Clay 4-62 Sand, shale, sandstone	42 45 57 60

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)
Bernard, Louis	770828	406500	5173200	103	100	19	78	10	10	0-11 Clay till 11-100 Sandstone, claysand	86 86
MacDonald, Donald	810728	406500	5173300	76	100	25	65	5	5	0-3 Till 3-76 Claysand, sandstone	66 71 75 76
Matthews, Mrs. Jack	820812	406500	5173300	120	100	23	87	8	10	0-12 Clay till 12-120 Clay, lcrd sandstone, claysand	105 115
Gallant, Reg	830629	406500	5173300	100	100	30	62		7	0-2 Clay 2-100 Claysand, sandstone, sand	66 71 86 88
Hubert, West	841011	406500	5173400	75	100	35	58	5	7	0-1 Clay 1-75 Claysand, sandstone	66 66 73 75
MacDonald, Keir	860917	406500	5173400	110	100	40	84			0-2 Clay 2-110 Sandstone and claystone	90 93 109 110
MacNevin, Mrs. Glen	750625	406500	5173510		95	15	26	12	4	0-15 Till 15-83 Clay, sand, sandstone	37 40 77 80
McBayne, Angus	760617	406650	5173400	80	75	25	47	8	8	0-6 Till 6-80 Claysand, sandstone	56 59
Island Tel Comp.	781205	406700	5172900	90	100	25	42	15	10	0-9 Clay till 9-90 Clay, shale, sandstone, claysand	60 65 80 85
A.T.O. Property Ltd.	850910	406700	5173700	60	50	20	35			0-3 Clay 3-60 Sandstone and claystone	42 46 57 60
A.T.O. Property Ltd.	850910	406750	5173700	60	50	20	35			0-3 Clay 3-60 Sandstone and claystone	35 36 47 50 57 60
Brisebois, J.	771103	406800	5173200	89	80	20	43	10	10	0-12 Clay till 12-89 Fractured clay, sandstone, claysand	46 50 80 85
Rayner, Alton	791019	406800	5173300	75	100	24	44	10	10	0-19 Clay till, clay shale 19-75 Claysand, sandstone, clay, shale	46 50 60 70
A.T.O. Property Ltd.	850910	406800	5173750	60	50	20	35			0-3 Clay 3-60 Sandstone and claystone	42 46 58 60
Texaco	860415	406810	5173200	23	75		7			0-15 Till, silt, some sandstone 15-23 Sandstone	20 23
Texaco	860415	406820	5173210	23	75		7			0-15 Till, silt, some sandstone 15-23 Sandstone	20 23
Texaco	860415	406830	5173220	26	75		22			0-15 Till 15-26 Sandstone, some claystone	24 26

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (lgpm)	Time (min)	Geology	Aquifers (Water Occurrences)
Texaco	860513	406830	5173340	23	75		20			0-20 Silt and gravel 20-23 Gravel	20 23
Texaco	860415	406840	5173230	23	75		11			0-15 Till, some sandstone 15-23 Sandstone	20 23
Texaco	860513	406840	5173250	23	75		23			0-19 Silt and gravel 19-23 Claystone and gravel	20 23
Texaco	860415	406850	5173200	23	75		12			0-15 Till, silt, some sandstone 15-23 Sandstone	20 23
Texaco	860513	406850	5173260	24	75		20			0-12 Till and mud 12-24 Sandstone and claystone	21 24
Texaco	860415	406860	5173240	23	75		20			0-15 Till, silt, some sandstone 15-23 Sandstone, some claystone	20 23
Texaco	860513	406860	5173270	32	75		28			0-7 Till and siltstone 7-32 Sandstone and claystone	31 32
Texaco	860513	406860	5173280	22	75		14			0-14 Till, silt and sandstone 14-22 Sandstone	20 22
Texaco	860415	406870	5173250	23	75		12			0-14 Till, silt, some sandstone 14-23 Sandstone	20 23
Texaco	860415	406880	5173260	23	75		10			0-15 Till, silt, some sandstone 15-23 Sandstone	20 23
A.T.O. Property Ltd.	850909	406850	5173750	60	50	22	35			0-3 Clay 3-60 Sandstone and claystone	45 48 56 60
A.T.O. Property Ltd.	850909	406852	5173752	65	50	25	35			0-3 Clay 3-65 Sandstone and claystone	55 58 64 65
Rafferty, Norbert	810115	407100	5173100	60	75	27	32	5	5	0-4 Clay, sand, till 4-60 Claysand, sandstone	40 43 52 55
Gain, Thomas	840810	407100	5173300	50	50	15	37	10	5	0-3 Clay 3-50 Claysand, sand, sandstone	40 43 45 48
Stiliker, Donald	800313	407200	5173400	70	50	22	42	10	10	0-8 Clay till 8-70 Clay shale, sandstone, claysand	55 58
Malone, Austin	770517	407500	5173500	79	60	20	42	7	10	0-16 Clay till 16-79 Sandstone, claysand	65 75
Buell, Gerry	780319	407599	5173393	60	70	25	44	10	10	0-11 Till 11-60 Fractured claysand, sandstone	54 57

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (lgpm)	Time (min)	Geology	Aquifers (Water Occurrences)			
Campbell, Don	750414	407600	5173500		85	15	33	8	15	0-12 Clay till 12-72 Shale, sand, sandstone	60	63	65	68
Andrews, Lillian	770616	407600	5173500	70	80	15	31	8	10	0-12 Clay till 12-70 Fractured claysand, sandstone, clay	35	40	60	65
Adams, Nellie	770110	407600	5173500	85	90	21	44	8	10	0-12 Clay till 12-85 Sandstone, claysand	80	85	75	80
Gorill, Richard	830602	407700	5173300	80	50	25	34		5	0-3 Clay 3-80 Claysand, sandstone	42	45	58	60
Smallman, Dale	811116	407900	5173500	80	75	10	35	5	5	0-3 Till 3-80 Claysand, sandstone	45	48	64	67
		Averages		83		22	43	9						

APPENDIX II

WATER QUALITY DATA

APPENDIX II
Water Quality Analyses
O'LEARY

Name&Date		Easting/Northing	Parameters Ca	Mg	Na	K	Hard.	Alk.	Cl	SO4	P	NO3	NH4	pH	Fe (T)	Fe (D)	Mn	Cu	Pb	Zn
M. Campbell	800704		34.0	8.00	5.5	1.45		138	9	< 5	0.10	1.4	< 0.2	8.2		< 0.1	< 0.02	0.02	< 0.1	0.60
Co-operative	800704		30.0	7.00	6.0	0.90		89	11	11	0.06	2.1	< 0.2	7.9		< 0.1	< 0.02	0.05	< 0.1	0.36
Corinthian Lodge	860522	406800/5173250	57.0	13.94	8.8	1.72	200.9	166	35		0.12	< 0.2		7.2	< 0.1	< 0.1	0.16	0.03	< 0.1	0.47
Wilfred Dennis	850612	405850/5173300	90.5	6.05	29.0	0.91	251.8	262	60		0.10	2.4		7.4	< 0.1	< 0.1	< 0.02	0.04	< 0.1	0.44
Allison Ellis	861106	406300/5173450	44.2	16.92	7.9	1.59	181.3	172	19		0.04	< 0.2		7.0	0.5	< 0.1	0.51	0.04	< 0.1	0.11
Kent Ellis	860709	406470/5173386	60.9	17.65	9.3	1.42	227.0	206	30		0.12	0.7		7.3	< 0.1	< 0.1	0.91	0.12	< 0.1	0.29
Warren Ellis	840327	406460/5173200	54.5	19.03	10.2	1.33	214.0	224	31		0.12	2.8		7.7	< 0.1	< 0.1	0.75	0.05	< 0.1	0.02
Warren Ellis	840619	406460/5173200	76.0	0.19	9.9	1.46	193.5	239	34		0.06	< 0.2		7.2	< 0.1	< 0.1	1.08	< 0.02	< 0.1	0.51
Warren Ellis	871222	406460/5173200	25.6	13.72	6.7	2.81	120.6	123	8		0.39	0.5		7.8	0.9	< 0.1	< 0.02	< 0.02	< 0.1	< 0.02
Jim Gallant	870105		59.9	24.33	13.5	2.21	252.4	225	29		0.38	0.7		7.2	0.4	< 0.1	1.35	< 0.02	< 0.1	0.05
Wesley Hubert	850307	406500/5173400	44.5	14.32	9.5	0.98	172.5	212	38		0.10	< 0.2		6.9	3.0	< 0.1	1.17	< 0.02	< 0.1	0.11
Lidstone's B.B.	870303	406400/5173200	131.7	24.42	61.0	2.03	433.6	325	90		0.10	12.5		6.6	1.5	< 0.1	0.10	0.40	< 0.1	2.64
Angus MacBain	780412	406700/5173450	50.0	12.00	13.8	3.10	190.0	128	28		0.04	6.0	0.2	6.9	0.1	< 0.1	0.05	< 0.02	< 0.1	0.06
Edward MacDonald	781118	406350/5173550	67.0	31.50	9.0	1.25	395.0	177	50		0.06	14.0	< 0.2	8.1		< 0.1	0.03	< 0.02	< 0.1	< 0.02
Helen MacDonald	861229		19.6	5.52	8.8	3.03	72.8	16	26		0.04	8.0		6.4	0.3	< 0.1	0.04	0.03	< 0.1	0.59
Keir MacDonald	860819	406400/5173400	56.7	21.55	12.0	1.65	232.4	209	35		0.15	< 0.2		7.1	1.7	< 0.1	0.83	< 0.02	< 0.1	0.28
D. MacEachern	820706	406470/5173380	77.0	17.60	11.0	1.40	265.0	207	37	30	0.10	< 0.2	< 0.1	7.2	0.1	< 0.1	1.15	0.09	< 0.1	1.23
H. MacWilliams	870421	406500/5173300	49.1	12.79	11.9	3.46	176.1	173	29		0.06	1.5		6.9	0.4	< 0.1	0.26	0.12	< 0.1	0.15
Jean Pate	871020		50.5	19.70	10.0	2.29	210.6	228	29		0.12	< 0.2		7.4	1.0	< 0.1	0.87	0.03	< 0.1	1.09
Marcia Pate	780412	406800/5173250	45.0	7.30	14.0	5.20	160.0	124	21		0.04	1.1	0.2	6.9	0.5	< 0.1	0.20	< 0.02	< 0.1	0.07
Marcia Pate	850730	406500/5173250	47.1	9.47	13.3	4.50	158.6	152	23		0.10	1.3		7.3	0.3	< 0.1	0.20	0.07	< 0.1	0.93
B. Phillips	851113	406351/5173450	78.2	20.26	20.6	1.27	279.4	265	45		0.17	1.0		7.2	< 0.1	< 0.1	< 0.02	< 0.02	< 0.1	0.36
Radio Shack	800704		38.0	6.50	7.0	0.90		119	15	13	0.06	2.1	< 0.2	7.5		< 0.1	0.06	0.10	< 0.1	2.00
Old Sandpile	800501		42.5	3.50	130.0	4.50		68	1900		0.02	0.2	< 0.2	8.0			0.28	0.05	< 0.1	1.90
Scotia Bank	800704		42.0	7.50	8.5	0.90		113	21	< 5	0.06	2.7	< 0.2	7.5		< 0.1	< 0.02	0.15	< 0.1	
Jeff Smallman	851113	406350/5173450	63.9	18.01	17.4	1.71	234.0	253	40		0.14	< 0.2		7.1	< 0.1	< 0.1	< 0.02	< 0.02	< 0.1	0.10
Herbie Strang	870618		133.3	16.24	20.0	1.01	400.0	270	60		0.10	1.1		6.8	< 0.1	< 0.1	< 0.02	0.06	< 0.1	0.03
Robert Turner	781221	406400/5173300	40.0	7.00	20.0	1.40		91	20	40	0.06	1.8	< 0.2	7.2		< 0.1	< 0.02	< 0.02	< 0.1	0.05
Nellie Willis	871222		57.4	26.45	15.1	2.11	253.1	178	60		0.37	3.5		7.2	2.7	< 0.1	0.32	< 0.02	< 0.1	0.12
ADL Plant	860331	406500/5173400	76.0	33.42	14.8	7.00	339.0	273	90		0.06	< 0.2		7.9	3.4	< 0.1	6.05	0.02	< 0.1	0.29
ADL Plant	860411	406500/5173400	76.8	34.49	11.9	3.42	333.9	153	100		0.04	14.0		7.5	0.2	< 0.1	0.16	< 0.02	< 0.1	0.14
ADL Plant	860522	406500/5173400	65.0	22.99	9.4	2.70	256.0	141	75		0.12	9.0		7.4	< 0.1	< 0.1	0.12	0.03	< 0.1	0.46
ADL Plant (raw)	861029	406500/5173400	61.5	36.26	11.7		302.9													

Name&Date		Easting/Northing	Ca	Mg	Na	K	Hard.	Alk.	Cl	SO4	P	NO3	NH4	pH	Fe (T)	Fe (D)	Mn	Cu	Pb	Zn
ADL Plant (tr.)	861029	406500/5173400	54.5	37.86	11.9	3.08	292.8	173	70		0.07	11.0		7.4	< 0.1	< 0.1	0.21	0.06	< 0.1	0.20
ADL Plant	871027	406500/5173400	26.2	13.26	7.5	2.48	120.2	160	9		0.15	0.8		8.0	< 0.1	< 0.1	< 0.02	< 0.02	< 0.1	< 0.02
Hospital	810722	405720/5172720	40.0	14.90	8.0	1.20	161.0	123	24	8	0.08	2.1	< 0.1	7.9	< 0.1	< 0.1	0.02	0.25	< 0.1	0.74
Hospital	840403	405720/5172720	30.4	16.34	8.8	1.16	143.5	138	25		0.16	1.7		7.9	< 0.1	< 0.1	< 0.02	< 0.02	< 0.1	0.07
Hospital	841009	405720/5172720	29.9	14.36	8.9	1.16	134.8	130	31		0.10	2.6		7.6	< 0.1	< 0.1	< 0.02	0.03	< 0.1	0.53
Hospital	861124	405720/5172720	31.9	18.45	11.1	1.49	156.1	146	38		0.07	2.3		8.1	0.2	< 0.1	< 0.02	< 0.02	< 0.1	0.20
Hospital	880202	405720/5172720	31.3	16.06	12.1	1.34	144.5	138	40		0.17	2.3		7.5	0.2	< 0.1	0.04	0.04	< 0.1	< 0.02
Elementary Sch.	820610	405770/5172790	12.0	11.80	9.0	2.10	78.0	139	16	13	0.04	1.6	< 0.1	7.2	0.4	< 0.1	0.15	1.38	< 0.1	1.49
Elementary Sch.	840403	405770/5172790	30.7	17.27	8.8	1.63	148.5	150	15		0.16	1.7		7.0	< 0.1	< 0.1	0.13	0.14	< 0.1	0.20
Elementary Sch.	850212	405770/5172790	33.9	18.52	8.3	1.58	162.5	153	17		0.10	1.8		7.7	< 0.1	< 0.1	0.11	0.25	< 0.1	0.81
Elementary Sch.	870303	405770/5172790	39.9	19.10	9.0	1.47	179.1	155	17		0.08	1.7		7.5	0.3	< 0.1	0.14	0.67	< 0.1	0.28
Sr Cit. A (C)	841213	405440/5172830	33.4	12.71	6.0		135.7													
Sr Cit. A (H)	841213	405440/5172830	6.6	1.08	71.0		20.9													
Sr Cit. B (C)	841213	405440/5172830	31.6	13.66	7.6		135.1													
Sr Cit. B (H)	841213	405440/5172830	10.5	1.35	75.0		31.8													
Sr Cit. C (C)	841213	405440/5172830	29.0	12.82	6.1		125.2													
Sr Cit. C (H)	841213	405440/5172830	4.8	2.44	67.0		22.0													
Sr Cit. A (H)	850806	405440/5172830	1.8	0.33	73.0	0.28	6.1	109	14		0.10	2.5		7.7	< 0.1	< 0.1	< 0.02	< 0.02	< 0.1	0.03
Sr Cit. B (H)	850806	405440/5172830	1.1	0.45	74.0	0.22	5.0	104	18		0.08	2.8		7.1	< 0.1	< 0.1	< 0.02	0.29	< 0.1	0.15
Sr Cit. C (H)	850806	405440/5172830	5.5	0.45	78.0	0.54	16.5	105	15		0.12	3.0		7.8	< 0.1	< 0.1	< 0.02	0.05	< 0.1	0.45
Sr Cit. B (C)	860501	405440/5172830	30.6	14.91	7.7	1.05	138.4	105	26		0.10	1.9		7.1	< 0.1	< 0.1	< 0.02	0.14	< 0.1	0.26
Sr Cit. B (H)	860501	405440/5172830	3.9	0.63	69.4		12.3													
Sr Cit. A (C)	870303	405440/5172830	33.8	13.96	10.3	1.60	142.7	120	13		0.08	2.6		7.8	< 0.1	< 0.1	< 0.02	0.07	< 0.1	0.44
Sr Cit. A (H)	870303	405440/5172830	8.4	1.78	87.0		28.3													
Sr Cit. B (C)	870303	405440/5172830	32.6	16.42	8.6	0.96	149.3	120	21		0.08	3.1		7.8	< 0.1	< 0.1	< 0.02	0.38	< 0.1	0.08
Sr Cit. B (H)	870303	405440/5172830	4.8	2.08	91.0		20.6													
Sr Cit. C (C)	870303	405440/5172830	32.3	14.46	7.4	1.14	140.6	117	16		0.08	3.2		7.8	< 0.1	< 0.1	< 0.02	0.17	< 0.1	0.17
Sr Cit. C (H)	870303	405440/5172830	0.3	0.40	92.0		2.4													
		CDWS							250	500		10.0		6.5-8.5	0.3		0.05	1.00	0.05	5.00